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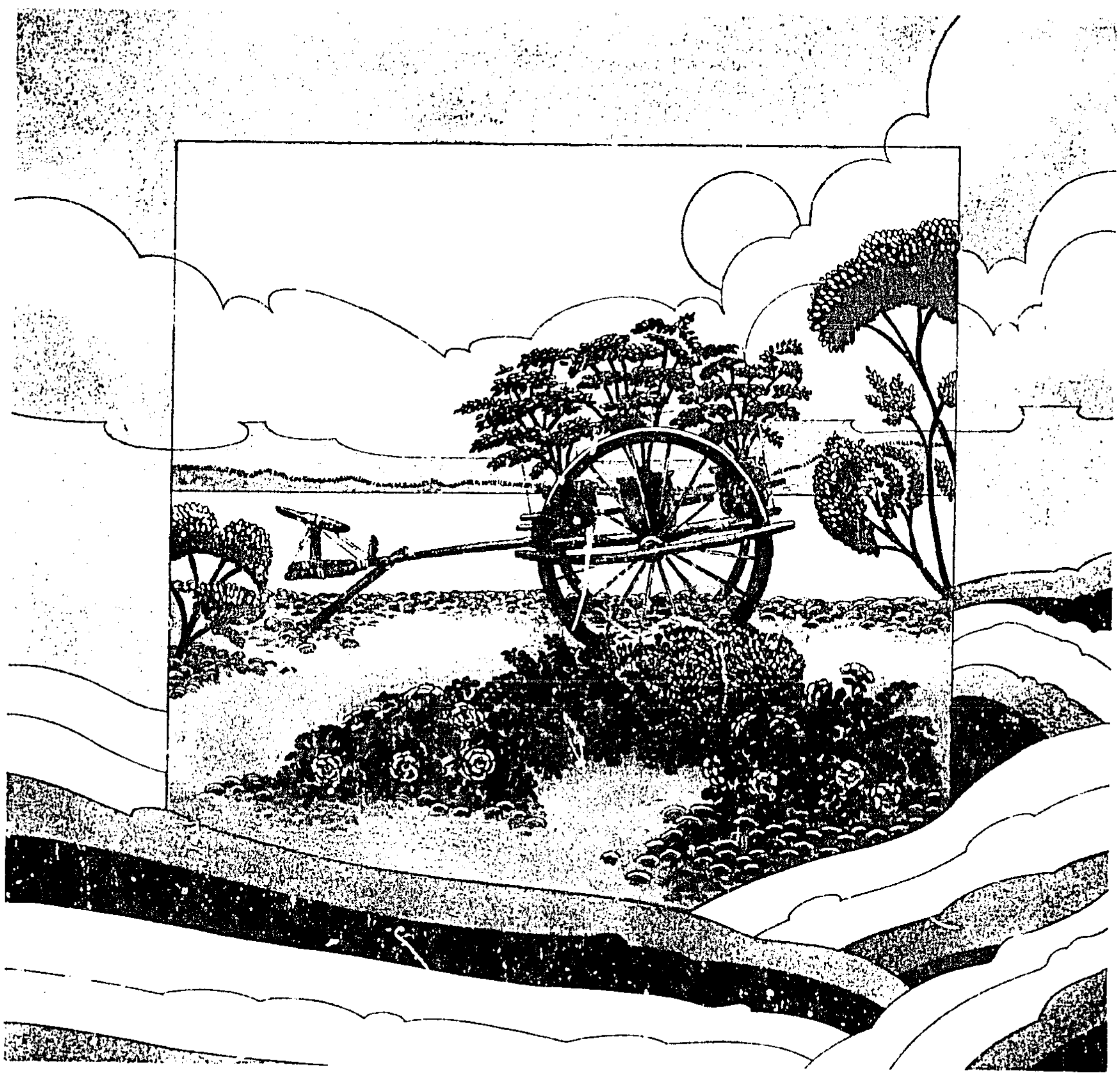
First International Conference

Kyusei Nature Farming



International Nature Farming Research Center

Khon Kaen University

U.S. Department of Agriculture

U.S. Agency for International Development

First International Conference on Kyusei Nature Farming

Proceedings of the Conference
at
Khon Kaen University
Khon Kaen, Thailand
October 17-21, 1989

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Sekai Kyusei Kyo Thai Kyokai, Thailand

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Foreword

The Agricultural Research Service (ARS) of the U.S. Department of Agriculture and the Science and Technology Bureau of the U.S. Agency for International Development (USAID) have worked cooperatively for almost a decade to provide technical support for improving soil and water management practices in dryland or rainfed agricultural systems in developing countries. The basis for this cooperative effort has been the USDA/USAID Dryland Agriculture Project which has focused its attention on improving the productivity and sustainability of dryland/rainfed farming systems in the Near East, Sub-Saharan Africa, and Southern Asia. During the last decade, food grain production per capita of some countries in these regions declined alarmingly. Much of this decline is attributed to the lack of proper soil and water management practices that led to the accelerated degradation of the natural resource base by soil erosion, nutrient depletion, desertification, salinization, and environmental pollution; often resulting in an irreversible loss of productivity.

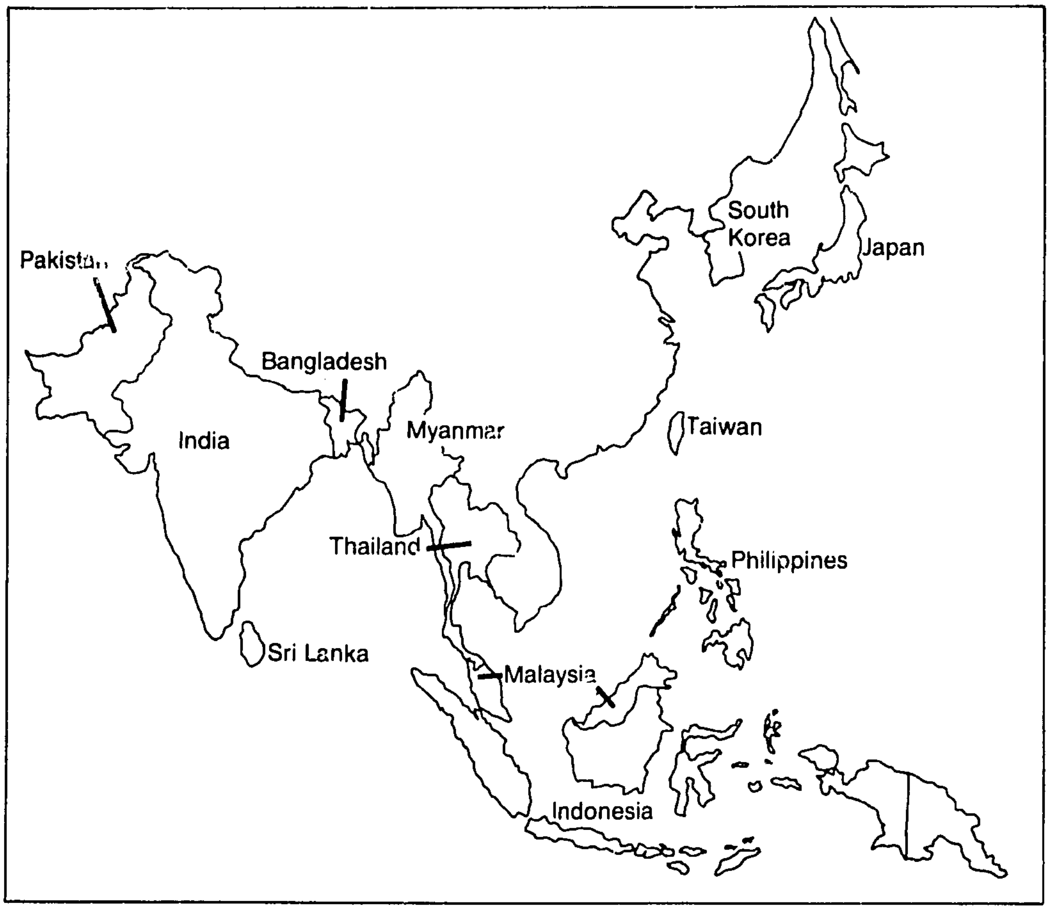
Many of the agricultural soils in countries of the Asia-Pacific Region are somewhat marginal with respect to crop production. Often they are inherently low in fertility, low in soil organic matter, and coarse-textured which makes them low in water-holding capacity and unsuitable for rice production. Rainfall patterns in this region are frequently erratic and unpredictable, and crop yields can be drastically reduced by drought even during the monsoon season.

There is probably no place in the Asia-Pacific Region where farmers face more severe problems and constraints to sustainable crop production than in Northeast Thailand. Consequently in February 1985, USDA, USAID, and Khon Kaen University co-sponsored the *International Workshop on Soil, Water, and Crop Management Systems for Rainfed Agriculture in Northeast Thailand.* The workshop was a major contribution because it critically assessed past research, identified gaps in our research database, established a consensus of research needs and priorities, and provided a sound basis for regional research and information networks to resolve urgent problems.

It is indeed appropriate that the organizing committee selected Northeast Thailand and Khon Kaen University as the site of the First International Conference on Kyusei Nature Farming. It is also fitting that the workshop focus is on the biological component of soils, and how agricultural sustainability can be enhanced through the use of effective soil microorganisms.

The Office of Agriculture of USAID's Science and Technology Bureau is pleased to have supported this workshop on nature farming and publication of the Proceedings. We hope that this will facilitate the development of more productive, profitable, and sustainable farming systems in the Asia-Pacific Region.

D.D. Bathrick
Director, Office of Agriculture
Science and Technology Bureau
U.S. Agency for International Development
Washington, D.C.



Countries Represented in APNAN

Preface

Kyusei Nature Farming is a system of farming that seeks to avoid the use of chemical fertilizers and pesticides. It also seeks to maximize the use of on-farm resources and minimize the use of purchased, off-farm inputs to conserve energy and reduce production costs. It seeks to produce nutritious, healthy and pollution-free food, and strives to revitalize agriculture in rural areas where soil productivity has been degraded through the misuse and mismanagement of the soil resource. The word *Kyusei* in Japanese means *saving*, and broadly interpreted Kyusei Nature Farming means saving the world through natural or organic farming methods.

Kyusei Nature Farming encompasses five requirements:

1) It must produce high quality food to enhance human health.

2) It must be economically and spiritually beneficial to both farmers and consumers.

3) It must be sustainable and easily applied.

4) It must conform to nature and protect the environment.

5) It must produce enough food for the world population.

The principles of Kyusei Nature Farming are somewhat similar philosophically to other natural farming methods such as *organic*, *regenerative*, and *alternative* agriculture that advocate soil quality as the fundamental basis for healthy crops and healthy people.

An added dimension of Kyusei Nature Farming is that it often employs technology involving beneficial microorganisms as inoculants to increase the microbial diversity of agricultural soils which, in turn, can enhance the growth, health, and yield of crops. The technology is referred to as effective microorganisms (EM) and was developed by Professor Teruo Higa, a scientist at the University of the Ryukyus in Okinawa, Japan. The promising results of research conducted with EM by Dr. Higa was a major incentive to organizing and convening the First International Conference on Kyusei Nature Farming that was held during October 17-21, 1989 in Khon Kaen and Bangkok, Thailand. The objectives of the Conference were threefold:

1) To review and discuss the current state-of-the-art of nature farming in countries of the Asia-Pacific Region.

2) To discuss the concept of effective microorganisms and report the results of research using EM technology.

3) To consider establishing a network of national scientists in the Asia-Pacific Region that would advance our knowledge and understanding of nature farming, and to enhance its successful application through research and technology transfer.

The Conference was co-sponsored by Sekai Kyusei Kyo (Atami, Japan), the International Nature Farming Research Center (Atami, Japan), the Thailand Ministry of Agriculture and Cooperatives, and the USDA/USAID Dryland Agriculture Project. The Conference was attended by more than 200 participants from 14 countries, including Bangladesh, Brazil, India, Indonesia, Japan, Korea, Malaysia, Myanmar, Pakistan, Philippines, Sri Lanka, Thailand, Taiwan, and the United States. Technical papers were presented on aspects of organic farming and nature farming in these countries, and on various approaches, strategies, and alternative practices that would foster the development of more productive, profitable, environmentally-sound, and sustainable farming systems in the Asia-Pacific Region.

A major achievement of the Conference was the founding of the Asia-Pacific Natural Agriculture Network (APNAN), a nongovernmental, nonpolitical scientific organization whose overall goal is to promote research, development, and implementation of natural agricultural practices, and technologies in the Asia-Pacific Region. The specific objectives of APNAN and details concerning its future activities are reported in Section VII (Appendix).

We hope that the Proceedings of this First International Conference on Kyusei Nature Farming will help to develop improved communication and exchange of technical information among scientists throughout the Asia-Pacific Region who have an interest in natural farming systems.

Organizing and Program Committee:

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The editors would like to thank Jean Newcomb, Information Staff, Agricultural Research Service, USDA, for her many significant contributions during the course of publication. These include designing the cover, assisting with the format, and serving as a technical consultant to the printer and contractors.

We would also like to thank Nancy Ward, National Program Staff, Agricultural Research Service, USDA, for her diligence in preparing the manuscripts.

Abbreviations

ADB	Asian Development Bank
APNAN	Asia Pacific Natural Agriculture Network
ASEAN	Association of South East Asian Nations
CIAT	Centro Internacional de Agriculture Tropical, Columbia
CIMMYT	Centro Internacional de Mejoramiento de Maiz y Trigo, Mexico
ESCAP	Economic and Social Commission for Asia and the Pacific
FAO	Food and Agriculture Organization, United Nations
ICRISAT	International Crops Research Institute for the Semiarid Tropics, India
IDRC	International Development Research Center, Canada
IITA	International Institute for Tropical Agriculture
INFRC	International Nature Farming Research Center
IRRI	International Rice Research Institute, Philippines
RRIM	Rubber Research Institute of Malaysia
SAARC	South Asian Association for Regional Cooperation
UNDP	United Nations Development Program
USAID	U.S. Agency of International Development
USDA	U.S. Department of Agriculture

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Section I
Opening Ceremony

Background Report

Dr. Tawisuk Santawisuk
Dean
Faculty of Agriculture
Khon Kaen University
Khon Kaen, Thailand

Your Excellency Chairman, Lt. General Chawal Kanchanakool
The Governor, The President of Khon Kaen University
The President of Sekai Kyusei Kyo
Distinguished Participants
Ladies and Gentlemen,

On behalf of the organizing committee, I wish to extend our cordial welcome and appreciation of your participation in this First International Conference on Kyusei Nature Farming. Also, I would like to take this opportunity to express my sincere appreciation to the International Promotion Committee of Kyusei Nature Farming of Japan with the cooperation of Sekai Kyusei Kyo Thai Kyokai for their great contributions and efforts, without which, this important event would have never been made possible.

Kyusei Nature Farming is a farming method which was initially advocated by Mokichi Okada of Japan, the founder of Sekai Kyusei Kyo in 1935. It is based on his belief that "The world can be transformed into a paradise by eradicating disease, poverty and conflict."

This philosophy of Mokichi Okada for saving the world is a treasure of mankind which should be shared by the whole world regardless of religions and ideologies. Motivated by this idea, we have decided to hold an International Conference on Kyusei Nature Farming, for the purpose of contributing to world peace and environmental conversation by providing a forum for discussions on the potential applications of the principles of Kyusei Nature Farming throughout this region and worldwide.

The following requirements which are not seen in conventional farming methods, are vital components of Kyusei Nature Farming:

1) It must produce superior food for the advancement of human health.
2) It must be economically and spiritually beneficial to both farmers and consumers.
3) It must be sustainable and be easily practiced by anybody.
4) It must conform to nature and maintain the environment.
5) It must produce sufficient food for the expanding world population.

Consequently, the method of Kyusei Nature Farming is considered to be an agricultural system offering the means to solve many problems arising from modern agricultural methods, and is now drawing great attention from all over the world. The method has achieved many good results in Thailand and Taiwan, as well as in Japan. Additionally, field tests have also been started in Brazil and the United States. Experimental results were presented at conferences of the International Federation of Organic Agriculture Movements (IFOAM) held in 1986 and 1989. Since then, we have received numerous requests from around the world for reference materials on the principles and practical applications of Kyusei Nature Farming in various countries.

To effectively comply with such requests and to further the understanding of Kyusei Nature Farming worldwide, the Faculty of Agriculture of Khon Kaen University, the University of the Ryukyus with Professor Higa, and the International Promotion Committee of Kyusei Nature Farming decided to organize an International Conference on Kyusei Nature Farming during October 17-21, 1989, at Khon Kaen. The conference consists of a series of country reports, discussion of research needs and priorities, and excursion trips to view the agriculture of Central and Northeastern Thailand. Thailand is honored to serve as a forum for the discussion and exchange of ideas between 65 visiting scientists from 14 countries and more than 150 Thai scientists. The proposed specific objectives are as follows:

1) To evaluate the country reports on nature farming;

2) To determine research needs and priorities on nature farming;

3) To establish an international, nongovernmental and nonpolitical commission on the nature farming system; and

4) To investigate the feasibility of a research network that can extend the knowledge and experience based on Kyusei Nature Farming.

Now the time has come for me to invite the Director of Policy and Planning of Green Esarn, Lt. General Chawal Kanchanakool, to deliver the speech and inaugurate the First International Conference on Kyusei Nature Farming. Thank you.

Opening Address

Lt. General Chawal Kanchanakool
The Director of Policy and Planning of
Green Esarn Project of the Royal Thai Military, Thailand

Mr. Governor
Mr. President of Khon Kaen University
Mr. President of Sekai Kyusei Kyo Kyokai of Japan
Distinguished Guests
Ladies and Gentlemen,

It is indeed my great pleasure to have the opportunity to address this distinguished gathering today.

First of all, I wish to extend a cordial welcome to all participants, particularly to the foreign delegates who have come a long way to join this First International Conference on Kyusei Nature Farming. It is also a pleasure to express my hearty appreciation to the Sekai Kyo Kyokai of Japan, the Faculty of Agriculture of Khon Kaen University, the Ministry of Agriculture and Cooperatives, and the Green Esarn Project of the Royal Thai Military, Thailand for making this important event possible.

We are well aware that modern agriculture is striving to produce sufficient food to meet the demand of the world's population which is dramatically increasing. In meeting this demand, there is a growing concern that much of the food produced may not be safe or of sufficient quality for the consumer. This concern is due to the excessive use of chemical fertilizers and pesticides in conventional production agriculture. Residues from these chemicals persist in both foods and the environment, and thus present a hazard to human and animal health. At the same time, these residues can interrupt natural processes and ecosystems that can result in the degradation of soil quality and the loss of soil productivity.

I am delighted to hear that the specific goal of the Kyusei Nature Farming movement for the year 2100 is to establish an agricultural system, both regionally and worldwide, that utilizes natural processes to ensure the production of sufficient, high quality food; conserves energy; lowers production costs; enhances health and safety; protects the environment; conserves natural resources; revitalizes agricultural practices in the rural areas; and improves the overall quality of life. This is a highly appropriate philosophy and should be the ultimate goal of both developed and developing countries so that sufficient, wholesome food is produced for an expanding world population while conserving and protecting the environment and natural resource base.

Therefore, the assistance provided by the Sekai Kyusei Kyo Kyokai of Japan through the Faculty of Agriculture of Khon Kaen University for establishing cooperative research on the Kyusei Nature Farming system is gratefully accepted. It is an honor and distinct privilege to offer my sincere best wishes to all participants of this conference for a productive and successful program.

Ladies and gentlemen, now the time has come for a very auspicious moment. It is a great privilege for me to officially declare the First International Conference on Kyusei Nature Farming open and wish that all of you have the most successful event ever.

Welcome Address

Dr. Nopadol Thongsopit
The President of Khon Kaen University
Khon Kaen, Thailand

Your Excellency Chairman
The Governor
The President of Sekai Kyusei Kyo Kyokai
Overseas Participants and Distinguished Guests,

On behalf of the staff and the organizing committee, I wish to extend our cordial welcome and appreciation of your participation in this First International Conference on Kyusei Nature Farming.

As you well know, there is increasing concern over the health and environmental problems associated with the use of chemical fertilizers and pesticides in agricultural production. The main objective of this conference is to encourage and stimulate interest and study of the Kyusei Nature Farming system and its use of effective microorganisms that can degrade toxic chemicals and pesticides in agricultural ecosystems, enhance the growth and yield of crops, and provide safe, high quality food. The high priority areas which demand immediate attention are the conservation of energy in agriculture, efficient use of natural resources and protection of the environment. I hope that this conference will provide alternative practices and options that both our Thai farmers and farmers worldwide can use to sustain the productivity of their lands and their profitability in the years ahead.

It is a great honor for the Faculty of Agriculture of Khon Kaen University, and Khon Kaen University itself, to host this conference since one of the major purposes of this university is to promote the development of the rural agricultural sector. I am sure that this conference will contribute towards this end by increasing our knowledge and understanding of the principles of Kyusei Nature Farming and the effective utilization of beneficial microorganisms in agricultural practices. The organizing committee will do their best to help you enjoy your stay in Khon Kaen. If you need help with anything, please do not hesitate to ask them.

Lastly, I wish to thank everyone again and welcome you to the First International Conference on Kyusei Nature Farming.

Section II
Keynote Speech

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Effective Microorganisms: A Biotechnology for Mankind

Teruo Higa
University of the Ryukyus, Okinawa, Japan

Good Morning everybody. First I would like to express my deep gratitude to Lt. General Chawal Kanchanakool, Director of Policy and Planning. of the Green Esarn Project of Royal Thai Military, Thailand, who generously accepted to be the Ceremony Chairman of this Conference, Khon Kaen University, and Sekai Kyusei Kyo Thai Kyokai, as well as many other people who endeavored to make this Conference possible.

I would also like to welcome the participants of this Conference from various countries.

As I have described in the brochure of this Conference, the reason and purpose of holding this Conference originated from Kyusei Nature Farming, which was first advocated in 1935 by Mokichi Okada for saving the world. Okada also founded Sekai Kyusei Kyo, a religious organization in Japan, intending "to create paradise on earth by eradicating disease, poverty, and conflict."

In the 1930s, when chemical fertilizers and agricultural chemicals started being used generally, Mokichi Okada realized the harm of such chemicals through his own experience, and warned of the long-term adverse effects on farming systems that used these chemicals.

He predicted that "the farming method which neglects the power of soil, crops, and nature, damages the soil and the cultivation environment, and crops produced with such a method exert harmful influences on the mental and physical health of human beings, creating a new crisis for mankind."

To avoid such a crisis, he advocated the establishment of Kyusei Nature Farming, which does not depend on chemical fertilizers and agricultural chemicals. He stated that "the principle of Kyusei Nature Farming is to learn from the great power of nature, which is beyond human understanding, and to allow the power of the soil to be fully exhibited by taking good care of the soil."

Without his great courage and deep insight, it would not have been possible to give such a warning at a time when the use of chemical fertilizers and agricultural chemicals was thought to be the solution for the food problems of mankind.

Unfortunately Okada's prediction came true. Since Rachel Carson's book *Silent Spring* was published in 1962, problems caused by the random use and misuse of agricultural chemicals and chemical fertilizers have frequently been cited in industrialized nations. Consequently, the world began to seriously consider the harm of agricultural chemicals and chemical fertilizers as well as that of other chemicals and their contribution to environmental problems.

As a result, the whole world is now trying to solve such problems through legal restrictions as well as by developing safer agricultural materials and safer ways to use them. Much of the world's agriculture today, however, is based on a system which requires agricultural chemicals and chemical fertilizers, and thus, they are inevitably used as necessary evils.

Therefore, if one tries to adopt a farming method which does not use chemical fertilizers and agricultural chemicals to produce safe food, it is perceived as organic agriculture or primitive nature farming.

Various movements of organic agriculture are in progress around the world with the highest priority on the safety of food. Most of them, however, are established only in limited areas or special regions where necessary organic substances can be easily obtained. As such, these movements have only limited potential for replacing present agricultural methods of food production which are economical and productive for an expanding world population.

Kyusei Nature Farming was advocated in 1935 foreseeing such an impasse. The ultimate goal of Kyusei Nature Farming is to save mankind based on the correct view of nature and to secure the foundation of human existence through the production of abundant healthy food, which is the most fundamental requisite for Okada's ideal, that is, "to create paradise on earth by eradicating disease, poverty, and conflict." A typical scenario of the destruction of mankind is the occurrence of disease caused by food shortages or harmful food, poverty caused by disease, and conflict caused by disease and poverty.

The problem of the rapidly increasing world population is destined to cause global environmental disruption and cannot be solved by extending the present system of food production. An increasing number of people believe that the present situation will lead to the destruction of mankind even if no war occurs. As part of the solution, Kyusei Nature Farming must be an agricultural system which can eliminate such negative factors. There are several requirements which Kyusei Nature Farming must satisfy to become such a system.

The first requirement, "to produce superior food for maintaining and improving human health," is based on the idea that one's health depends on the safety and quality of food consumed throughout a lifetime. Various medical problems today can be related to the quality of food consumed. It is clear that agricultural methods which depend on chemical fertilizers and agricultural chemicals cannot solve this problem.

As far as the first requirement is concerned, it has been fully proved that organic agriculture and conventional nature farming satisfy it. Except for a few special cases, however, these farming methods in their present state cannot be extended to agriculture as a whole and still be economically beneficial to both producers and consumers, partly because of the problem of obtaining enough organic substances.

The second requirement is "to bring economic and spiritual benefit to both producers and consumers." Although farmers are well aware of the negative effects of using chemical fertilizers and agricultural chemicals, they have no other choices. When farmers cannot take pride in producing high quality food, agricultural production and marketing systems will decline. Furthermore, consumers can truly enjoy eating, which is the root of health and well-being, only if they have safe food.

The third requirement is "to be practiced by anybody and to be sustainable." Since growing crops is the basis of life, a farming method cannot secure the foundation of human existence unless it can be practiced by everyone. If it requires its practioners to learn the complicated names of pesticides and fertilizers, or if it requires special training or special machines, only a limited number of people will adopt and apply a particular farming method. Such a situation will clearly produce new crises of world peace, as can be seen from the food production strategies of many developed countries. The requirement of sustainability is obvious. Satisfying it together with the second requirement leads to an agriculture which can be continued with pride, and which may also solve many of the problems which agriculture faces today.

The fourth requirement is "to conserve nature and to responsibly protect the environment." The abuse of chemical fertilizers and agricultural chemicals pollutes not only fields but also rivers, the sea, and other environments, and is directly related to environmental pollution on a global scale. Such agriculture is causing a boomerang effect, and can be said to be suicidal. It is a known fact that the everlasting existence of mankind cannot be sustained without conserving natural resources and protecting the environment. However, there are few agricultural systems which can truly satisfy this requirement. On a global scale, environmental safeguards include prevention of increased atmospheric levels of carbon dioxide, destruction of the ozone layer, and desertification of fragile lands.

The fifth and ultimate requirement is "to responsibly produce enough food for the increasing world population." Although it is extremely difficult to perfectly satisfy even one of the first four requirements, Kyusei Nature Farming, as intended by Okada, must fundamentally solve the problem of food supply and human health, in addition to satisfying the other four requirements. Some people assert, that it is only idealism. It is impossible to achieve it in reality. The only way to solve these problems is to control the world population and to establish stricter environmental standards. While such measures should also be taken, Kyusei Nature Farming cannot be the one Okada advocated unless it satisfies these requirements.

Okada specified a few conditions for Kyusei Nature Farming to satisfy those five requirements.

The first condition is to turn soil into a nutrient storehouse, that is, to establish a technique which increases soil fertility and the availability of plant nutrients. The second is to establish a technique which enables soil to become like a skilled worker and to produce more crops as more consecutive plantings are made. The third is not to pollute the soil and to allow the power of soil to be fully expressed, in turn suppressing diseases and insects. He states that these conditions lead to paradisiacal agriculture, which does not require plowing and other labor-intensive practices.

We now realize that Kyusei Nature Farming, as advocated by Okada, is not a natural farming system in which no work is done and everything is left to nature. It is also fundamentally different from organic agriculture, which first returns to the ancient farming method of using no chemical fertilizers or agricultural chemicals, in seeking a new method of farming. In a broader sense, both nature farming in which everything is left to nature, and organic agriculture are possible ways whereby we might fulfill the requirements of Okada's Kyusei Nature Farming. We need to realize that in conventional nature farming many failures, misunderstandings, blame, and criticisms have occurred because associated problems were misunderstood, and there was no attempt to resolve them.

Based on Okada's philosophy, research has been conducted over the past 50 years. However, it was difficult to exceed the level of organic agriculture, and it has become clear that we now need a technical system which is fundamentally different from conventional agricultural techniques.

You may wonder if soil can be made a storehouse of nutrients, allowing consecutive plantings, and if crops can be cultivated economically without plowing soil and without using chemical fertilizers and agricultural chemicals. It is extremely difficult with conventional agricultural techniques or with its extensions.

Conventional agriculture is a system which is dominated by approaches or symptomatic therapy, and which requires chemical fertilizers and agricultural chemicals. The largest mistake of this system is that it is based on inorganic chemistry, and it does not consider organic chemistry and vital biological phenomena in the soil.

The current method of soil management is mainly based on the chemistry (acids, alkalis, and inorganic nutrients) and physics (air permeability, water permeability, and water-holding capacity) of the soil. The biology of soil is considered only through the application of organic substances for increasing humus. Therefore, the soil classification is also based on their chemistry and physics. There is no systematic classification of soils based on their biology.

It has become clear from our studies that the characteristics of soils depend largely on the microorganisms which inhabit them. Accordingly, we have classified soils into four types: disease-inducing soil, disease-suppressive soil, zymogenic soil, and synthetic soil.

The reason why conventional agricultural systems have limitations is that they are based on the inorganic approaches mentioned earlier, and that the soil management practices eventually transform farmland into disease-inducing (putrescent) soil. Soil putrefaction, that is, the putrefaction of organic substances plowed into soil, accompanied by malodors, is a phenomenon of organic substances decomposing into inorganic substances.

Putrefaction is also a phenomenon which produces unstable, intermediate products and a large amount of heat, while organic substances are decomposed into inorganic substances by microorganisms. Such intermediate products and heat are harmful to ordinary animals and plants, and cannot be utilized as useful energy. The ancient teaching that one should "use fully-decomposed compost" is based on this fact. This is also the reason why crops tend to be withered or infested with diseases and harmful insects if insufficiently decomposed compost is used.

Crops are frequently infested with disease and harmful insects when soils become putrescent. This is also the case when crops become unhealthy. This mechanism of disease occurrence is common to both animals and plants. Diseases and harmful insects exist in nature to decompose living things that have succumbed to various stress factors. Hence, crops are rarely infested with diseases or harmful insects when they are grown under suitable conditions. Some people believe that worm-eaten vegetables are safe because they are grown without pesticides. Such vegetables, however, are unhealthy and therefore cannot be good for the human body. The prevention of disease and insect infestations starts by purifying the cultivation environment. However, since most of the microorganisms in nature are putrescent, conditions suitable for putrefaction are easily established if the cultivation environment remains undisturbed.

Chemical fertilizers and pesticides were viewed as an effective means of increasing food production on a limited amount of farmland. However, if they are not properly used, or are excessively used, they may damage intrinsic functions of the soil. The more chemicals are used, the more positive ions are accumulated, changing once healthy soil into a disease-inducing environment with frequent infestations of diseases and insects.

Accordingly, insects and microorganisms which did not cause significant damage to crops suddenly become pathogenic, and diseases and insects resistant to pesticides appear one after another. New pesticides are required, forming a vicious circle. The same phenomenon can also be seen in medicine.

Organic agriculture movements were motivated by efforts to correct such a situation by halting the use of chemical fertilizers and agricultural chemicals and changing conventional, chemical-based agriculture into organic agriculture. To secure the production of safe food, they first returned to the old agricultural method of using no chemical fertilizers or agricultural chemicals, and then started to establish a safe agricultural system different from conventional agriculture.

Generally, the productivity of infertile and degraded soils is restored by raising the humus content using fully-decomposed compost. At the same time compost functions as a soil conditioner to improve soil physical properties. When organic agriculture is practiced on poor farmland, soil fertility is gradually improved, and disease and insect infestations are reduced. It normally takes four to five years to achieve this.

A soil in which disease and insect infestations are suppressed is normally called a disease-suppressive soil. Most native forest soils are strongly disease-suppressive. If a forest is cleared leaving the surface soil intact, and crops are cultivated, they grow very well for the first few years when the disease-suppressive power of the soil is still effective. As the humus content decreases, and soil fertility declines, the soil becomes a disease-inducing soil, and diseases and insects begin to frequently infest crops.

Crop productivity can be increased without using chemical fertilizers and pesticides when soil is changed into a disease-suppressive soil by adding organic substances. This was considered to be the best management practice in the age when no agricultural chemicals were available. At present, organic agriculture still maintains the same philosophy.

I have so far described the fundamental philosophy of Kyusei Nature Farming, and problems of present day conventional agriculture. I would like to now describe a new technique which can overcome the problems of today's agricultural systems, that is, the fundamentals of food production and environmental conservation which are based on the principles of creation.

The basic philosophy of this technique is to reestablish the balance of energy in nature without causing pollution. The decomposition of organic substances through putrefaction is a typical process causing pollution. The extent of environmental pollution is increasing worldwide because of the lack of understanding that in a broader sense the entropy increase (pollution) of the earth occurs because we do not purify harmful substances in a timely manner.

Although it is a principle of nature that any existing matter inevitably ages and degenerates, there is also a principle of regeneration according to which harmful substances decompose into more useful substances. The earth, which started from inorganic substances, can sustain so much life only because processes and systems have evolved that can transform harmful substances into harmless substances in a self-contained way, or as a self-multiplicative energy source.

Based on experiments we have conducted on the application of microorganisms to crops, it has become apparent that the effect of microorganisms largely differs, depending on soil conditions and methods of application. In particular, we found that zymogenic and synthetic microorganisms coexisting in soil suppressed the generation of heat and gas when fresh organic substances were plowed into the soil, and were extremely effective for the growth of crops and increased yields. As I mentioned before, if fresh organic substances are plowed into soil which has putrescent microorganisms, harmful gas and heat are generated, affecting crops. However, we have observed that if microorganisms in soil are predominantly zymogenic, organic substances plowed into soil are transformed into amino acids and saccharides (carbohydrates) which are useful to plants, and can be recycled as a source of organic energy.

Familiar examples of products produced in such processes are fermented food, such as miso (soybean paste), soy sauce, and fermented soybeans, and fermented feed, for example, silage for livestock. Unlike putrefaction, fermentation is the process in which organic substances are transformed into useful water-soluble substances through the process of decomposition. In this process, protein is transformed into amino acids, while starch, cellulose and lignin, are transformed into saccharides.

If soil is putrescent, organic substances release their energy into the air in the form of gas and heat, which cause pollution, and are then decomposed into inorganic substances, returning the soil organic matter to a low equilibrium level. On the other hand, if the soil is zymogenic, organic substances are stored in the form of water-soluble energy, and used as organic energy by plants, producing no gas or heat, and, therefore, causing no pollution. Since energy once fixed in plants is reused in this process without being transformed into carbon dioxide or water, the process can function as a technique to suppress the energy loss, due to carbon dioxide and heat pollution, or a technique to recover it. That is, the energy of the earth is recovered through agricultural production and stored as food. Since most of the energy once fixed as organic substances can be reused in this process, theoretically, food shortages will not occur if the population of the world increases at the present growth rate.

This process can be simply realized by artificially changing the microflora in soil to those of the zymogenic type through the application of zymogenic microorganisms to the soil. Although this technique has drawn attention in the area of food and feed, no one ever thought of applying it to crop cultivation because the phenomenon is extremely exceptional in nature.

The main microorganisms working in this process are synthetic types such as photosynthetic bacteria and nitrogen-fixing bacteria. Photosynthesis is the process by which water is split into oxygen and hydrogen inside chlorophyll using sunlight as energy. Oxygen is released into the air and hydrogen is used to reduce carbon dioxide, producing saccharides or carbohydrates. Photosynthetic bacteria do not use water as a hydrogen source to reduce carbon. But they can use heat or sunlight as energy and hydrogen from other sources, such as methane gas, indole, skatole, methyl mercaptan, and various organic acids. These compounds are produced during the decomposition of organic substances. Photosynthetic bacteria perform incomplete photosynthesis.

In this way, harmful heat and other intermediate products of putrefaction are recycled for the synthesis of organic substances by photosynthetic bacteria, resulting in no net production of heat and gas. These photosynthetic bacteria are often found in the jungles and forests of the humid tropics and they have a high reproductive ability. In particular, if they exist symbiotically with nitrogen-fixing bacteria in the rhizosphere, plants grow extremely well without fertilizers. This happens because organic substances synthesized by photosynthetic bacteria are absorbed as organic energy sources by plants.

If soil is changed to a zymogenic and synthetic soil in which zymogenic microorganisms and synthetic ones coexist, not only can the organic substances be effectively used, but the soil fertilizes itself under optimum humidity and temperature conditions. Since such soil can synthetically or zymogenically transform harmful substances produced in natural processes, putrescent decomposers and disease-producing bacteria cannot establish themselves.

Agriculture is said to be a fight against diseases, insects, and weeds. As I have already mentioned, it is possible to suppress the infestation of diseases and insects by enhancing the disease-suppressive power of soil and by further changing the soil to a zymogenic and synthetic soil. It has already been shown that this principle can be applied to weeding.

Herbicides exert the worst influence in the soil, such as environmental pollution and the destruction of the life sphere of microorganisms. However, herbicides are used because they save a large amount of labor, and thus, are said to be necessary evils.

If zymogenic and synthetic microorganisms are introduced into soil, weed seeds simultaneously germinate without going through dormancy. In fields which used to be infested with a large amount of weeds, weeds grow like turf. If these weeds are plowed into soil with a tractor, weeding thereafter is hardly necessary. For paddy fields, this method of weed control is much more effective than with herbicides.

Furthermore, perennial herbs and bulbous plants ferment and wither if their roots are plowed up and wounded, and they totally disappear from the field after a few plantings. The aboveground parts of weeds, which are plowed into soil at the same time, become water-soluble in soil and serve as fertilizers. Thus, we cannot but thank weeds.

In this way, the problem of obtaining organic substances is also solved, and the fertilization of soil can be easily done if a proper combination of weeds and green manure crops is considered.

It has also been shown that the production rate of humus is increased two to threefold, lowering the soil bulk density and thereby improving its tilth, air permeability, water permeability, and water-holding capacity. These results lead directly to nonplowing cultivation as well as simpler farming operations.

The consecutive planting of tomatoes in my laboratory is now in the 18th planting. Furthermore, nonplowing cultivation is now in the practical stage, and producing considerably better results than cultivation with plowing, since the soil microflora and fauna are stabilized.

The application of effective microorganisms is not limited to agriculture. They are now utilized to abate malodors in wastes, to treat and process sewage, and to purify water in rivers and lakes.

Environmental pollution and food production problems on a global scale are now threatening mankind. To solve these problems, it is necessary to further learn from nature and to develop various kinds of technologies such as Kyusei Nature Farming, following Okada's philosophy of saving the world. It is necessary that research scientists and engineers fully realize that any technology or biotechnology can be truly beneficial to mankind only if it is used to develop and maintain the health and well-being of mankind.

Finally, I would like to express my deep gratitude to Sekai Kyusei Kyo, which offered tremendous support to the realization of this Conference, and Mr. Yasushi Matsumoto, the president of Sekai Kyusei Kyo, who is present here today, as well as to Mr. Yamaguchi, Mr. Morishita, and Mr. Kosugi, Dietman of Japan, and Mr. Kaieda, a former Dietman of Japan, who came here all the way from Japan to support this Conference. Thank you.

Section III
Regional Experiences I

Adapting Nature Farming to Large-Scale Vegetable Production

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ABSTRACT. Over the last decade, nature farming has been adapted for the large-scale production of vegetable crops at a farm in Lompoc, California. Successful management techniques include permanent beds, use of soil amendments and effective microorganisms. Specific practices such as soil fertility management, weed and insect control are described.

Background

Our attempts to adapt nature farming to commercial-scale vegetable production began in 1981 on a 10 acre farm in Camarillo, California. At Camarillo we developed our permanent bed system for large-scale production and were able to grow top quality produce with respectable yields.

The accomplishments at Camarillo led The Naturfarm to move in 1988 to a much larger site to provide a commercial-scale example of nature farming methods and the permanent bed system. On its 75 acres of cropland near Lompoc, California, The Naturfarm staff continue to fine-tune and develop the permanent bed system and other techniques, adapting the principles of nature farming to large-scale production of vegetable crops in the United States.

Basic Principles of Nature Farming

Nature farming is based on a philosophy and a spiritual way of life that acknowledges the earth and the soil as a living being. Nature farming seeks to enhance the *life force* of the soil and the plants growing in the soil; it avoids all practices that are unnatural, especially those that use pesticides and herbicides. The cultural practices that characterize nature farming are deliberately chosen to enhance the growth of desirable life forms. These practices can be separated by function: soil tilth, soil fertility, and pest management.

In nature farming we seek as much as possible to apply the patterns found in nature to the agricultural setting. Our desire to respect nature and preserve the natural soil structure and soil profile with its natural horizons led us to the idea of experimenting with equipment-managed permanent beds in the field. We felt that this technique could be very effective if transferred to large-scale production as a means of reducing compaction, preserving the natural soil profile, and nurturing soil life, thereby optimizing productivity and conserving energy.

Permanent Beds to Enhance Soil Tilth

Initial Bed Preparation

Initial bed preparation consists of a deep subsoiling followed by chisel plowing to break up soil compaction without inverting the soil. Rototilling then breaks up the clods, and a spike-tooth harrow smooths the surface. At the same time, a furrowing device mounted on the middle cultivating bar of the tractor creates *permanent* paths between the 80 inch wide beds. The tractor and all farm equipment will use these permanent paths during all subsequent field operations.

Bed Maintenance Between Crops

The *permanent* beds are maintained from crop to crop. After a crop is harvested, a forage harvester chops all remaining crop residues. If it is a heavy residue crop, the residue is chopped, blown into a wagon and hauled out of the field to be used in making compost. In the case of a light residue crop, it is chopped and left on the surface of the soil, forming a layer about 1/2 inch (1 to 2 cm) thick, evenly spread over the bed. Compost is spread on the beds at 3 to 5 tons per acre. Then the compost and chopped residues are rototilled into the top 3 to 4 inches (7 to 10 cm) of soil. This is followed by a thorough irrigation that includes the application of effective microorganisms (EM)† through the irrigation system. Throughout all of these operations, the tractor wheels, forage harvester wheels, and compost wagon wheels follow the same path so that the permanent bed, the central crop-growing area, is not compacted or driven upon by any of the farm equipment. In effect this provides a controlled-traffic pattern.

A week or so later, and after decomposition of the crop residues is well underway, we till again with spear-point cultivators mounted behind the tiller. They penetrate deeper than the tiller to prevent compaction and the development of a *tiller-pan.* They do not invert the soil, but rather create vertical channels into the lower soil profile. Next, the spike-tooth harrow and/or smooth harrow, mounted in the rear of the tractor, smooths the bed for planting crop seeds. A cross-section of the finished bed reveals a loose layer in the top 10 to 15 cm and firmer soil below, with channels to the lower profile allowing easy root penetration. After the preceding tillage operations, the soil profile approximates a natural soil, and becomes more natural as successive crops are grown and as a beneficial soil microflora is developed.

Soil Fertility Management

The Naturfarm's soil fertility program consists of the use of compost, cover crops and effective microorganisms (EM).

The forage harvester, used for chopping crop residues, is also used to collect materials for making compost. Dry grasses are mixed with fresh green-chop from the vegetable fields. The compost pile is layered: a layer of dry grass followed by a layer of fresh green-chop. Each layer is thoroughly watered, and EM 4 is applied to enhance the composting process. By the next day, the temperature of the compost pile has usually increased to approximately 150°F (65.5°C).

Mixed cover crops including nitrogen-fixing legumes and fibrous grasses are planted at least every two years to maintain and improve soil tilth and fertility. Sometimes they are incorporated directly into the soil and EM is applied to accelerate their decomposition. At other times, the biomass is removed for composting.

An effective way of applying EM on a large scale is using an injector tank which connects to the irrigation line. The concentrated EM solution is placed in the tank, and EM can then be precisely metered into the irrigation system and evenly spread over the growing area with overhead sprinklers.

Weed Management

The basic concept in weed management is to sufficiently reduce the number of weeds to allow good crop development and eliminate reseeding which always makes weed management more difficult. Total eradication of all non crop plants is usually impractical and not necessarily desirable. Weeds can provide benefits in both pest and fertility management by serving as alternate host or trap crops for beneficial and/or harmful insects, and by accumulating nutrients for recycling.

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† EM (Effective Microorganisms) is a group of mixed cultures of microorganisms that have been developed and patented by Dr. Teruo Higa of the University of the Ryukyus in Japan for the purpose of improving soil tilth and fertility, and of increasing crop yield and quality. Each formulation (EM 2, EM 3, EM 4) is dominated by a different group of organisms that collectively can achieve specific results.

EM 2 and EM 3 are used on growing crops to help make nutrients available from organic matter and soil minerals. EM 2 is a complex culture solution dominated by yeasts, photosynthetic bacteria, and ray fungi; EM 3 is 95 percent photosynthetic bacteria. EM 4 is used to help decompose crop residues and other forms of organic matter added to the soil. EM 4 is dominated by *Lactobacillus* bacteria. Research on the use of EM is underway in the U.S. and elsewhere. EM has been extensively researched in Japan and is used by many farmers there.

Preplanting Weed Germination

When the seedbed is ready for planting, and before planting crop seeds, preplanting weed germination is encouraged. The field is sprinkler irrigated to germinate weed seeds near the surface. Then, the spike-tooth harrow is used with its teeth set to penetrate only about one inch (3 cm) to avoid bringing new weed seeds to the surface. The roots of the young weed seedlings are exposed and they quickly wither and die. This preplanting weed germination technique vastly reduces weed pressures in the following crop.

Planting

Precision planters are used to plant vegetable seeds in 2 to 5 parallel rows (depending on the type of crop), allowing future cultivation of the entire bed at one time.

Primary Cultivation

For precise cultivation of small-leaved vegetables, a double disk cultivator is very effective. It can be used when the crop is at a very young stage since it throws material away from the plant row and prevents burying the young seedlings. The double-disk cultivators can even be used without preplanting weed germination if weed pressure is not too great, because cultivating can be done when the weeds are very young and can be easily controlled. This saves time, water, and energy. Large-leaved vegetables, like squash, have an initial plant size that is too large for the disks. A configuration of knives and sweeps are used to eliminate weeds between the rows.

Thinning

Following the primary cultivation, the crops remain on 2 to 5 inch wide (5 to 13 cm) bands of noncultivated soil. During hand thinning this band is cut through with a hoe when any weeds remaining in the row are removed, leaving plants spaced for growing to maturity. Crops that are not thinned (beets, spinach, carrots, etc.) are hand weeded as it becomes necessary.

Secondary Cultivation

Before reaching the harvest stage, there may be one or two other cultivations. Depending on crop type and size, a configuration of knives and sweeps are used to cultivate the soil between the crop rows. This removes or prevents a second generation of weed growth.

Roguing

Hand hoeing of weeds missed in the foregoing operations, and those which sprout in the rows after thinning, is practiced where necessary. This provides the crop with sufficient space if there is heavy weed pressure, and prevents reseeding of weeds.

Additional Methods

An alternate method for large-seeded crops (beans, squash, corn, etc.) is to plant them approximately 3 inches (7 cm) deep following the preplanting weed germination, and then irrigate them thoroughly. As soon as possible, the spike-tooth harrow is used to kill germinating weeds in the surface soil and to create a *dry mulch* of loose soil above the germinating crop seeds. The crops can then emerge easily through the loose *mulch* and establish themselves with very little pressure from annual weeds.

Insect Management

The nature farming philosophy views pests and diseases as symptoms of an ecological imbalance or toxic condition. This could be the result of past practices (e.g., toxic condition due to previous use of agricultural chemicals), or current management practices that are pushing the farm ecosystem out of balance. A pest outbreak or infestation, or an air- or soil-borne disease is a natural ecological reaction indicating the need to restore the farm to a more favorable ecological balance.

The first line of defense in the nature farming pest management program is the creation of a fertile, healthy soil and farm ecosystem that supports the growth of healthy, vigorous crops, and provides a biological system of checks and balances. Techniques utilized include: selection of crop varieties appropriate to the climate and soil of the farm and resistant to certain insects and diseases; intercropping; creation of an on-farm insectary using break strips of alfalfa and mixed pasture species as habitats for beneficial insects and as trap crops for pests; mechanical removal of pests using a *Cycle-vac* insect vacuum; beneficial insect releases to supplement those that occur naturally on the farm; and applications of effective microorganisms (EM). If intolerable levels of economic damage begin to occur, organically-allowable biocides (such as pyrethrins, soaps, etc.) would be used. However, we have not chosen to use any of these to date.

Kyusei Nature Farming in Japan

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ABSTRACT. The nature farming movement in Japan has gained momentum in recent years among farmers, consumers, and the governmental officials. The search for more natural, nonchemical means to improve soil tilth and fertility, and to control pests has led to the use of effective microorganisms (EM). Trials with EM have now been conducted for a wide range of vegetable crops, legumes, fruits, and field crops. Results have been promising in terms of high yields, suppression of weeds, and reduced need for agrichemicals. Recommendations for the successful use of EM are given.

On this occasion of the First International Conference on Kyusei Nature Farming, I would like to describe the history of Kyusei Nature Farming in Japan.

The organic agriculture and nature farming movements in Japan began to develop in the early 1970s. They were motivated by the publication of a book entitled *Fukugoh Osen* (Complex Pollution), written by Sawako Ariyoshi in 1975. The author was inspired by the shocking report, *Silent Spring*, written by Rachel Carson in 1962. Ariyoshi's book reports the results of her investigation of environmental pollution in Japan.

Currently, the movements and organizations that advocate organic agriculture and nature farming are closely related to consumer movements for safe and nutritious food. The number of Japanese farmers participating in such movements is about 50,000, and the sizes of their organizations range from a few farmers to tens of thousands of farmers. These movements have gained the support of the urban sector of society.

The Japanese Ministry of Agriculture, Forestry and Fisheries also recognizes the importance of the movements of organic agriculture, and established the Office of Organic Agriculture in 1989. This was accomplished through the activities of the Japan Organic Agriculture Study Group and the Association of Dietmen for Studying Organic Agriculture. There were 96 Dietmen that supported this action.

This development resulted in the expansion of the number of farmers in the organic agriculture movement in Japan to about one percent of the total farmers. Most of them, however, are small-scale farmers.

Foreseeing this situation in 1935, Mokichi Okada presented the ideals of Kyusei Nature Farming, which have contributed significantly to the organic agriculture and nature farming movements in Japan today. Kyusei Nature Farming advocates a production system which does not disrupt the natural ecosystem and seeks to achieve the production of healthy agricultural products without the use of chemical fertilizers and pesticides. The social situation at the time of its advocacy, however, was not mature enough to accept Kyusei Nature Farming. Consequently, it was practiced by only a few farmers who enthusiastically embraced the philosophy of Kyusei Nature Farming and its principles.

On the other hand, the decline in soil productivity and crop yields from the degradation of farmland, environmental pollution from agrichemicals, and the hazards to human and animal health from modern agriculture, have become important social problems.

In this regard, Kyusei Nature Farming is now attracting the attention of many people since it utilizes the natural ecosystem while conserving and protecting the environment. Presently in Japan, there are about 1,500 farmers practicing Kyusei Nature Farming in paddies, fields, and orchards. However, further research is needed to determine the cost, productivity, labor requirements, and overall profitability of Kyusei Nature Farming. This information must be known before there is widespread acceptance of Kyusei Nature Farming by conventional farmers.

Since the current technique of Kyusei Nature Farming concentrates on the utilization of compost, Kyusei Nature Farming has not yet satisfied all of the requirements for agriculture of the 21st century, that is:

1) High productivity,

2) Labor saving,

3) Energy saving,

4) Safety, and

5) Marketability.

In 1983, we started cultivation experiments using a new technique which follows the original philosophy of Kyusei Nature Farming. The conventional technique of Kyusei Nature Farming satisfies only two of the requirements, that is, energy saving and safety. Kyusei Nature Farming which adopts the technique of using effective microorganisms (EM), developed by Dr. Teruo Higa of the University of the Ryukyus, has good prospects of satisfying all five requirements.

The experimental cultivation for testing the effect of EM was performed at the Ishigaki Farm in Okinawa Prefecture for three years starting in 1983. The results of this study are shown in Table 1. The highest yield of peanuts and carrots were obtained from nature farming using EM, followed by conventional agriculture, and conventional nature farming. The effect of EM was dramatic. EM was also very effective on sugarcane, pineapple, potatoes, Daikon radish, cucumber, and leafy vegetables.

After these basic experiments, we began nationwide cultivation trials in 1986. Since Japan has an extreme range of climatic zones, from subarctic to subtropical, trial cultivations could be conducted at locations which are representative of the world's principal agroclimatic zones.

In the subarctic zone, EM was found to be effective in large-scale production of wheat, potatoes, soybeans, adzuki beans, onions, and carrots.

In the temperate zone, trial cultivation was performed in paddies, fields, and orchards. With EM, it is now possible to grow tomatoes, cucumbers, and eggplants in greenhouses, which was considered to be very difficult before. Furthermore, with EM we succeeded in growing fruits such as apples, Japanese pears, cherries, grapes, and especially European grapes without pesticides. This was virtually impossible before.

The results in the subtropical zone are those reported for the Ishigaki Farm in Okinawa (Table 1).

Table 1. Yield of Peanuts and Carrots Grown in Three Different Farming Systems.

Crop	Conventional Nature Farming	Conventional Agriculture	Nature Farming Using EM
	....	*kg ha^{-1}*	....
Peanut	500	2,000	3,500
Carrot	10,000	25,000	28,000

Table 2. Outline of the Basic Experiments and Trial Cultivation Using EM.

Type of Study	Year	Area	Farmers	Crops
		ha	*No.*	*No.*
Basic EM Experiments	1983-85	5	1	15
Trial Cultivations	1986	30	200	50
	1987	60	470	80
	1988	150	1,030	120

As shown in Table 2, the area of cultivation has been largely increased, and EM has proved to be effective for many crops. Cultivation using EM is now in the transition stage from trial cultivation to practical cultivation. Considerable progress is expected this year from trial cultivations using EM. From these results of nationwide trial cultivations using EM, the following conclusions can be made about the five requirements for a more sustainable agriculture in the future:

1) **High Productivity.** High productivity is restored and maintained by the reduction of disease and insect pests in soils and crops. Direct effects due to the increase of nitrogen-fixing bacteria and VA mycorrhizal fungi has also been observed. This effect comes from EM 2 and EM 3.

2) **Labor Saving.** There are many examples in the trials where the time required for weeding in paddies was absolutely zero. This was considered to be impossible before. The large reduction of weeding hours has also been observed in fields and orchards. This is possible because soil aggregation and soil structure are enhanced by the use of EM, and soil tilth is considerably improved. The suppression of weeds in paddies is facilitated by EM 4, and in fields and orchards by EM 2 and EM 3. There are also cases in which the work of cultivation management was largely reduced because EM made nonplowing cultivation possible.

3) **Energy Saving.** This effect is obvious since Kyusei Nature Farming does not use chemical fertilizers and pesticides and, therefore, fossil energy required to synthesize those products is unnecessary.

4) **Safety.** This is also obvious because no chemical fertilizers or pesticides are used. Thus, the safety of the method and the crops it produces is ensured.

5) **Marketability.** The use of EM has improved the quality of crops and has overcome the limitations of conventional Kyusei Nature Farming such as pest-damaged and irregular crops.

This is the present state of Kyusei Nature Farming in Japan. In summary, I would like to make a few points which should be kept in mind when using EM.

The first is that EM is a living culture and, thus, fundamentally different from chemical fertilizers and other agricultural chemicals. Therefore, it is necessary to establish a soil environment which allows the survival, growth, and reproduction of the microorganisms in the EM cultures. In particular:

1) The soil pH must be adjusted. Since most soils in Japan are acid, the pH of paddies is adjusted to 6.0 and that of fields and orchards is adjusted to 6.5.

2) Soil must be kept moist. This can be done by using compost, grass mulch, and drip irrigation.

3) Organic materials must be added to soil if necessary. A humus content of about 3 percent is recommended.

4) EM must be diluted before application. In ordinary application, EM 2 is diluted by 1:1000, and EM 3 by 1:1000 to 1:2000. EM 4 should not be sprayed over leaves. If EM 4 is used for the treatment of soil, it should be diluted by 1:1000.

The second point is that there is no uniform instruction manual for the use of EM as there is for chemical fertilizers and pesticides. It is said that the only instruction manual for EM is that there is no manual. This is because the agroecosystems for crop production are different, and EM must be used in a way that is most suitable for each environment. Therefore, it is necessary to characterize the environment through careful observation and then establish the EM treatment. This approach is fundamental to agriculture. We believe that to strengthen the soil complex is to vitalize the earth and its harvest. The principle of Kyusei Nature Farming is to vitalize the earth, and its goal is to attain the health of mankind.

Prospects of Nature Farming for Rice Production in Indonesia

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ABSTRACT. Increased rice production is urgently needed in Indonesia to supply the food demands of an ever increasing population. Because of the growing shortage of good agricultural land, intensifying rice production on current farm land is the primary alternative. However, intensification without conservation of natural resources and protection of the ecosystem will lead to the degradation of the natural resource base and create problems in the production process that will likely require greater energy inputs.

Natural based cropping systems are the best agricultural alternative for avoiding the rapid degradation of natural resources, and for maintaining the stability, productivity, and long-term sustainability of our farming systems. An understanding of the complex interactions between effective natural resources and technological input is a vital prerequisite for promotion of rice production. Therefore, research on natural resources as an integral part of the process of agricultural intensification should be planned and implemented.

Introduction

The long-term economic development program for Indonesia which began in 1969 continues to emphasize the importance of agricultural development because it is a necessary prerequisite for economic development. The long-term objective of economic development in Indonesia requires a practical and workable balance between a strong agriculture and a strong and productive industrial community. A strong agriculture means an efficient agriculture that is capable of conserving and protecting the natural resource base so that it is ecologically-sustainable, economically-profitable, and produces high quality agricultural products that conform to market demand.

This paper deals with the promotion of rice production. The main reason for selecting rice for such promotion is because rice is a staple food for most of the Indonesian people and provides 55 percent of their total calories and 60 percent of their total protein. Rice culture is also a major source of employment and income for at least 70 percent of the population in rural areas. Rice is primarily produced by small farmers of which 65 percent cultivate less than one hectare of land.

Before Indonesia first reached self-sufficiency in rice production in 1984, it was the world's leading rice importing country. Since then, Indonesia has again had to import rice. Therefore, the main objectives of Indonesia's rice production program are:

1) To increase rice production.
2) To increase farmer income.
3) To decrease rice imports and to use existing foreign exchange to import equipment needed for industrial development.
4) To achieve a long-term, self-sufficiency in rice production for Indonesia and a stable and equitable market price for farmers.

There are four main goals in the promotion of rice production for Indonesia. These are intensification, diversification, extensification, and rehabilitation. The implementation of these goals is intended to conform with local natural conditions. Nevertheless, since the natural resources for agriculture are very limited, intensification of production on currently farmed land is considered to be the highest priority.

Rice Production in Indonesia

Many factors influence the level of rice consumption in Indonesia. These include the economic capability of consumers, availability of rice in the marketplace which dictates the price, the existence of other carbohydrate sources at comparable prices, and consumer behaviour and prestige. The changes in per capita carbohydrate consumption of three major food sources are shown in Table 1.

There is a general trend in Indonesia, that increased rice consumption coincides with increased income as a result of economic development. People consume more rice as their standard of living improves.

Rice production in Indonesia has increased to fulfill the demand for rice and, consequently, rice imports have decreased. Rice production, harvested area, and average yield for 1968 to 1987 are shown in Table 2.

Table 2 shows that the increase in harvested area is not as large as the increase in rice production. The harvested area in 1987 was 9.94 Mha, a 23.9 percent increase compared to the harvested area in 1968. However, rice production in 1987 was 27.2 million Mg of milled rice, which is 133 percent higher than rice production in 1968. The increased production is mainly due to increased yield, rather than an increase in harvested area. For example, the yield average in 1987 was 2.74 Mg ha^{-1}, or 87.7 percent higher than the yield average in 1968. The yield increase is mainly due to technological inputs that have enhanced intensification. These include the introduction of high yielding varieties, increased use of nitrogen and phosphate fertilizers, improved cultural techniques, and improved irrigation practices. Pesticide usage to control pests that infest the crop has been relatively high. Production inputs which have been distributed for the intensification program from 1969 to 1986 are in Table 3.

Prior to 1969, Indonesian farmers practiced a traditional, subsistence-type agriculture. Rice varieties planted were mainly local selections which were well-adapted to local environmental conditions. Therefore, pest infestations were not a serious problem. However, these varieties were not responsive to chemical fertilizers. Seedlings were transplanted at a relatively late growth stage in order to avoid flooding and, thus, the regeneration process was not sufficient.

Table 1. Per Capita Consumption of Rice, Corn, and Cassava, 1969 to 1985.

Year	Consumption		
	Milled Rice	Corn	Cassava
	.... *kg y^{-1} capita $^{-1}$*		
1969	118	14.6	56.5
1970	108	17.8	51.2
1975	114	17.0	60.7
1980	131	17.2	71.0
1985	143	12.9	60.6

Source: Food Balance Sheet as cited by Rosegrant et al. (1987) in Indonesian Agricultural Research and Development Journal, Volume 10, Number 1, 1988.

Table 2. Harvested Area, Average Yield, and Production of Rice in Indonesia, 1968 to 1987.

Year	Harvested Area	Average Yield	Total Production
	Mha	*Mg ha⁻¹*	*10⁶ Mg*
1968	8.02	1.46	11.7
1969	8.01	1.53	12.2
1970	8.14	1.62	13.1
1975	8.50	1.79	15.2
1980	9.00	2.24	20.2
1985	9.97	2.66	26.5
1986	10.0	2.70	27.0
1987	9.94	2.74	27.2

Source: Directorate of Agricultural Development Program, Department of Agriculture, Indonesia, 1988.

Table 3. Distribution of Subsidized Fertilizers and Pesticides for the Intensification Program, 1969 to 1986.

Year	Urea	KC1	Insecticides	Fungicides	Rodenticides
	Mg	*Mg*	*kg*	*kg*	*kg*
1969	202,000	-	-	-	-
1970	308,000	-	-	-	-
1975	670,000	-	2,360,000	7,510	84,800
1980	1,680,000	8,780	6,370,000	43,400	73,800
1985	2,550,000	297,000	15,000,000	213,000	82,400
1986	2,610,000	296,000	17,200,000	439,000	85,900

Source: Indonesian Agricultural Research and Development Journal, Volume 10, Number 1, 1988.

The high production that is needed to achieve rice self-sufficiency in Indonesia has created new problems in the rice ecosystem involving the plant nutrient equilibrum. Most farmers believe that high rates of nitrogen fertilizer will produce proportionately higher yields. Consequently, they tend to use more and more nitrogen fertilizer. This is counterproductive since excessive use of nitrogen and phosphate fertilizer can cause nutrient imbalances that may suppress the availability of other important nutrients in the soil. For example, some rice producing areas now need other fertilizers in addition to nitrogen and phosphorus. These include sulphur, potassium, and micronutrients.

Another problem associated with the introduction of high yielding varieties is their increased susceptibility to pests and the concomitant increased use of pesticides.

Problems and Challenges of the Future Promotion of Rice Production in Indonesia

Rice self-sufficiency which was achieved in 1984 should be maintained in order to sustain the national food security. It is recognized that maintaining sustainable rice self-sufficiency involves complex problems and challenges. Among these is the declining rice producing area on the Island of Java because of an expanding area devoted to other crops. Moveover, with increased population growth, expansion of production into new areas is not proportional to the functional change of the rice area. This is because it is difficult to move people into newly developed areas, especially if these areas have a low production potential.

Therefore the primary goals that have been emphasized for promotion of rice production in Indonesia are: intensification for increasing soil productivity; diversification for increasing farmer income, minimizing risk, and suppressing pest population growth by creating variety in the ecosystem; expansion of the total agricultural land base, which often includes marginal soils of low fertility that require costly inputs and technology to attain acceptable yields; and rehabilitation of degraded agricultural lands.

By the year of 2000, the total population of Indonesia will be approximately 220 million people. This is 44 million more people than in 1988. Rice demand in 2000 is estimated at 37.5 million Mg of milled rice for human consumption, feed, industry, and additional stock to stabilize the price. In order to meet the food demand in 2000, the food crop area should be expanded from 18.5 Mha to 22.1 Mha. The general policy of intensification that has recently been implemented should be closely monitored to avoid any adverse health and environmental effects that can occur with the increased use of agricultural chemicals. Intensification should conform with the potential carrying capacity of the existing agricultural land resource base.

There are a number of problems that should be addressed in promoting the intensification of rice production in Indonesia.

The Availability of Plant Nutrients in Soil

During the early phase of the Indonesian agriculture development plan, nitrogen and phosphorus were considered the two major plant nutrients needed by the high yielding varieties. Today, however, the situation is quite different and additional plant nutrients are needed to sustain yields, including sulphur, potassium, and an array of micronutrients. The nutritional requirements of the rice crop and the availability of nutrients in soil and irrigation water should be calculated to ensure the proper amount of fertilizer for each field. Effective time and method of application are other important factors which can be exploited to avoid adverse effects from excessive fertilizer application and unbalanced nutrient levels in the soil.

High Yielding Varieties

Improved local varieties together with the improved cultural practices during the first phase of the rice production program resulted in increased yields. However, due to the narrow genetic variability in the breeding materials, the yield increase was limited to the maximum level of the base population. In order to establish a better balance between rice supply and demand based on a limited cropping area, improved breeding programs are needed to enhance the yield potential and adaptability of rice varieties. The main objective in rice breeding is to develop new high yielding rice varieties that will ensure optimum and stable yields. Other factors that should be considered in rice breeding are resistance to major pests and tolerance to environmental stresses.

Cropping Intensity

Increased cropping intensity is the only solution to a fixed or limited agricultural land base. Currently, the cropping intensity in the irrigated rice area is still less than 200 percent. In the rainfed area, cropping intensity is less than 150 percent. To expand the harvested area, cropping intensity for irrigated rice could be increased to approximately 250 percent, and the rainfed area to 200 percent. Hypothetically, the potential cropping intensity for the irrigated area is 300 percent but should probably be avoided because of the likelihood of increased pest infestations.

Diversity

Food crops are usually grown with clean cultivation since weeds or undesirable plants will compete for nutrients, water, and solar energy. Clean cultivation using a single high yielding variety on a large scale has contributed significantly to increased rice production. However, increasing pest problems have been observed under intensified production, which have led to a decline in yield. Less diversity of plant species—rice varieties have only one or few major genes of resistance—and plant structure has resulted in less diversity among insects. This has led to population growth of insect pests without any significant constraints. An outbreak of a major insect pest in an area which cultivates a single rice variety has often occurred in Indonesia with devastating results.

Pest Management

Increasing pest problems have been observed on large-scale intensification areas. Yield losses due to major pests vary widely according to pest species, varietal vulnerability, and the farmer's ability to cope with the situation. Factors which have been recommended in intensification can also contribute to the increased pest problem, including continuous and staggered planting, increased application of nitrogen fertilizer, heavy use and dependence on pesticides, and decline of varietal diversity over wide areas. These factors have probably contributed to the outbreak of a serious rice pest, the brown planthopper, during the last few years. Pest management which is based on the manipulation of several effective components of the rice ecosystem should decrease the need for pesticides.

Prospects of Nature Farming for Promotion of Rice Production

In general, agriculture is a human effort to exploit and manipulate natural resources for man's benefit. Agricultural activities are not always compatible with the interdependent nature of the major components of ecosystems. Therefore, the stability of agricultural ecosystems is quite different than that of natural ecosystems. The stability of agricultural ecosystems is artificial and man-made and requires continuous inputs of energy in the form of fertilizers, irrigation, and pesticides.

To meet the food demands of an ever increasing population requires that agricultural technology inputs be effectively integrated with the natural resource base. In practice, the technological inputs should be implemented judiciously.

Nitrogen fertilizer is a prospective component of natural resource-based rice production. Nitrogen resources in nature are derived from rainfall, decomposition of straw, and green manure. Recently, *Azolla spp.* have provided a potential source of nitrogen for irrigated rice. At present, however, the potential contribution of nitrogen from rainfall, straw decomposition, and other sources such as *Azolla* is not receiving sufficient consideration. Research is needed to establish credits for these natural nitrogen sources so as to minimize the amount of nitrogen fertilizer that has to be applied. There is some indication that rice plants are more susceptible to certain pests due to excessive application of nitrogen fertilizers. The excessive use of chemical fertilizers such as nitrogen and phosphorus can lead to a nutritional imbalance in soils. A proper balance or combination of chemical fertilizer and organic fertilizer will help to maintain adequate soil fertility and enhance soil productivity. Therefore, research on the use of organic materials as fertilizers is urgently needed.

It is a general hypothesis that intensification leads to increased pest infestation. When Indonesia began its intensification program by introducing high yielding varieties, chemical fertilizer, better irrigation, and cultural practices, pest infestations occurred coincident with those practices, and could only be controlled by applying pesticides. At that time, pesticides were used excessively to control pest infestations. This approach resulted in some serious adverse effects such as resistance of pests to certain pesticides, increased production costs due to pesticides, and decreased farmer benefits. To overcome this situation, integrated pest management has been intensively implemented. The main principle of integrated pest management is to manipulate the effective components of the agricultural ecosystem in maintaining pest populations below the economic threshold. The major components which play a role in maintaining low pest populations are ecosystem diversity, homogeneous planting to interrupt pest cycles, resistant varieties, balanced fertilizers, and judicious use of pesticides.

Pest management in rice ecosystems is generally divided into two phases i.e., preplanting phase and postplanting phase. The activities in the preplanting phase are determination of planting time (late or early) and selecting resistant varieties to major pests. Postplanting activities are monitoring of plant growth, pest populations and their natural enemies, and pesticide applications when necessary. However, pesticides should be applied judiciously when other activities cannot suppress the pest population below the economic threshold.

To support this approach, we must be able to identify the critical stage when a plant is most vulnerable to a certain pest. On the other hand, the life cycle of the pest itself must also be studied to identify the proper time of pesticide application so as to avoid adverse effects on natural predators. Natural resource-based cultivation as an alternative to current agricultural practices has the potential to sustain a stable, productive, profitable, and environmentally sound agriculture for the future.

Nature Farming in Myanmar

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ABSTRACT. Present agricultural systems in Myanmar follow the traditional methods which utilize the available natural resources combined with improved cultural practices. Although the use of synthetic chemicals such as fertilizers and pesticides have been well established in Myanmar's agriculture, the quantity actually used is much lower than the recommended optimum rates. Hence, there is no evidence so far that the use of such synthetic compounds in Myanmar have caused any serious disruption of natural ecosystems or environmental pollution.

However, because of increasing costs of agricultural chemicals and their uncertain availability, research is urgently needed to develop productive, profitable, and sustainable agricultural systems without the use of costly and hazardous synthetic agricultural chemicals.

Introduction

The use of natural resources for agricultural production has long been a traditional practice of farmers in Myanmar. Prior to the introduction of chemical fertilizers in the late 1960s, agricultural production was solely dependent on the use of farmyard manure (FYM) and locally available organic manures. The type and quantity of the organic manures used at different locations varied greatly, depending upon their availability.

When chemical fertilizers were introduced in the late 1960s, there were dramatic increases in crop yields. Introduction of high yielding varieties also helped to improve crop yields. Since fertilizer use by farmers has been considerably less than recommended, and because of the nutrient requirements of high yielding varieties, there has been a substantial depletion of plant nutrients from soils. This has resulted in a critical decline in soil fertility and productivity.

Farmers are beginning to recognize the problem of declining soil fertility when crops do not yield as much as expected. However, the restoration of soil fertility in most cases has not been achieved. And the increasing cost and uncertain availability of chemical fertilizers in the developing countries has led to higher production costs.

Under such circumstances, efforts to increase agricultural production, with decreased dependence on expensive and even hazardous chemical inputs, should be made. More effective ways and means of using natural resources would undoubtedly help to improve agricultural production in Myanmar.

Present Agricultural Systems in Myanmar

Agriculture is the mainstay of Myanmar's economy. Over 65 percent of the foreign exchange earnings come from agriculture. As such, future economic development will also be based upon the promotion of agriculture and agro-allied industries. For these reasons, the improvement of agricultural productivity has been accorded the highest priority in our national development programs.

Agroecological Aspects of Myanmar

Myanmar is a forest-clad mountainous country, with plateaus, valleys, and plains. The Tropic of Cancer divides the country into two main climatic regions, namely the tropical south comprising over two-thirds of Myanmar, and the sub-tropical, temperate north which comprises the remaining one-third of the country.

There are two distinct seasons; the dry season occurs from mid-October to mid-May and is followed by the wet season. There is a cold spell from December to February during the dry season.

The southwest monsoon, the major source of Myanmar's annual rainfall, occurs during May to October. The precipitation varies with both locality and elevation. The highest annual rainfall, varying from 250 to 500 mm, is in the coastal regions and in the northern part of the country; very low annual rainfall of below 100 mm occurs in the Dry Zone area, and moderate rainfall of 100 to 200 mm occurs in some parts of the country.

Major Crops Grown in Myanmar

Due to variations in agroecological conditions, more than 60 different crops are grown in Myanmar. They can be grouped into seven categories as follows:

1) **Cereals.** Rice, wheat, maize, and millets.
2) **Oil Seeds.** Groundnut, sesamum, sunflower, and mustard.
3) **Food Legumes.** Black mungbean, green mungbean, butter bean, red bean, pigeonpea, cowpea, chickpea, and soybean.
4) **Industrial Crops.** Cotton, jute, sugarcane, rubber, and tobacco.
5) **Food Crops.** Potato, onion, chillies, vegetables, and spices.
6) **Plantation Crops.** Tea, coffee, coconut, cocoa, oil palm, toddy palm, banana, and other fruits.
7) **Miscellaneous Crops.** Other crops which are not listed in the above groups.

Land Utilization

The present status of land use in Myanmar is summarized in Table 1. The area designated as arable wasteland is about the same size as the currently cultivated area, or some 12 percent of the total. The cultivated area could be expanded by developing the arable wasteland for agriculture, but it would require heavy capital investment to overcome the problems and constraints that limit crop production on these lands.

Table 1. Present Status of Land Use in Myanmar (1986-87).

Type of Land	Area	Percent of Total Area
	10^3 ha	%
Planted cropland	8080	12
Current fallow	1990	3
Culturable wasteland	8450	12
Reserved forest	10,100	15
Other forest (decontrolled)	22,300	33
Unclassified land not suitable for cropland	16,800	25
Total†	67,700	100

†Totals may not be precise due to rounding.

Table 2. Farm Size in Myanmar, Number of Farmers, and Total Acres in Each Category.

Farm Size	Number of Farmers	Total Area
ha	*10^3*	*10^3 ha*
Less than 2	2620	2460
2 to 4	1050	3060
4 to 8	490	2760
8 to 20	103	1120
20 to 40	1	37
More than 40	1	324
Total†	4270	9760

†Totals may not be precise due to rounding.

General Farming Practices in Myanmar

Under the government policy which gives the right of tilling the land to the actual tiller, the number of farmers with large holdings have substantially decreased while the number of farmers working on smaller holdings has increased accordingly (Table 2).

Mechanization in Myanmar's Agriculture

There are about 4,000 tractors in the Agricultural Mechanization Department which tilled 1.1 million acre-turns in 1988-89. Thus, a tractor tilled an average of 274 acre-turns. Since less than 6 percent of the total tillage is mechanized, the disruption of natural ecosystems, such as soil structure, from heavy machinery is not a serious problem in Myanmar. Human and animal power are utilized for most of the tillage operations.

Recent Agricultural Developments in Myanmar

Work has begun on many fronts to develop the agricultural sector in Myanmar.

Introduction of Chemical Fertilizers

The use of chemical fertilizers was initiated in the late 1960s. The domestic production of urea fertilizer is being supplemented with imported fertilizers. In 1987-88 total procurement of chemical fertilizers amounted to 0.40 million Mg, comprising 0.26 million Mg from domestic production, and 0.14 million Mg of imported fertilizers. The utilization of fertilizers by crops in 1987-88 totalled 0.33 million Mg, of which 70 percent or 0.23 million Mg was utilized for paddy. Fertilizers were also used for other crops such as wheat, groundnut, and sesamum.

Utilization of chemical fertilizers decreased by 54,000 Mg, compared with the previous year. While efforts were being made for effective use of chemical fertilizer, organizational efforts were implemented for systematic use of biofertilizers, rhizobium, and locally-available natural fertilizers to supplement chemical fertilizers.

Introduction of Pesticides

The use of pesticides began in the late 1960s as one of the measures taken to increase production in the agricultural sector in Myanmar. About 277 Mg of powdered pesticides and 121,000 liters of liquid pesticides were utilized in 1988-89.

In order to reduce the residual effects of conventional synthetic pesticides, attempts were made to use natural pesticides as substitutes. Extracts from the neem tree, *Azadirachta indica* (A. Juss) which has long been known to have insecticidal properties, were thoroughly investigated and found to be effective. As a result, a pilot plant for neem extraction was constructed in 1986-87 at Paleik village near Mandalay under the Burmese-German Plant Protection Program. In 1989-90, it is projected that 80,000 kg of neem seeds will be processed into 16,000 liters of neem extract. A 35 percent soluble concentrate of neem extract in water is effective in controlling a number of pests on different crops.

Introduction of Quality Seeds

Contact has been made with international institutions, like IRRI (Philippines), ICRISAT (India), IITA (Nigeria), CIMMYT (Mexico), and CIAT (Columbia), which will provide quality seeds of various crops.

Research work for the development of quality seeds was also undertaken in Myanmar to increase the yield per area and to improve crop quality. Quality seeds for paddy, wheat, maize, sesamum, sunflower, and coffee were multiplied and distributed to the farmers in 1988-89.

Introduction of Selective Concentrative Strategy (SCS)

The new rice production strategy designated as the *Whole Township Rice Production Program* using the new technology was first launched in 1977-78. The new technology required precise timing of plowing, harrowing, and transplanting, which was accomplished through a collective effort. The recommended plant population was 320,000 hills ha^{-1}, which is twice that normally used by farmers.

The program covers over half of the total area under paddy in Myanmar. Rice production increased by a remarkable 65 percent from 1974-75 to 1982, with the national yield increasing from 1.65 Mg ha^{-1} to almost 3 Mg ha^{-1}.

Selective concentrative strategy is also being utilized to improve the production of other crops such as maize, groundnut, sunflower, cotton, wheat, sorghum, jute, potatoes, and pulses.

Introduction of Integrated Pest Management

The integrated pest management program in Myanmar has four major components for improvement of crop production:

1) Use of resistant varieties;
2) Use of suitable cultural practices;
3) Use of biological control methods; and
4) Use of chemical control methods.

Introduction of Soil Conservation Practices

Terracing in the hilly regions was implemented with the following objectives:

1) To promote self-sufficiency for the native population of the hilly regions;
2) To increase productivity in the agricultural sector;
3) To change shifting cultivation practices to terracing; and
4) To prevent soil erosion and deforestation.

A total of more than 8,910 ha spread over seven divisions and States was under terrace cultivation in 1986-87.

Wind erosion is a very serious problem which causes extensive soil degradation and loss of soil fertility in the Dry Zone central plains of Myanmar. A windbreak program was implemented in 1988-89 in three townships. Twelve thousand seedlings of *Leucaena glauca* and *Cassia siamea* were planted on 202 ha of land.

This windbreak program is to be expanded to six townships in Magway Division in 1989-90.

Introduction of Organic Fertilizers

Farmers in Myanmar are faced with increasing costs and uncertain availability of chemical fertilizers. Moreover, the continued use of some synthetic fertilizers has had adverse effects on soil productivity. In view of this, farmers are being encouraged to increase their use of available organic wastes and residues as organic or biofertilizers.

Use of Animal Wastes

The use of animal waste, especially cattle manure, has long been practiced in Myanmar. The population of farm animals in Myanmar is shown in Table 3.

Table 3. Population of Farm Animals in Myanmar.

Animal Type	Year 1986-87	1987-88	1988-89
		10^3	
Cattle	9760	9920	10,100
Buffalo	2160	2190	2240
Sheep/goat	1480	1460	1500
Pig	2990	3060	3200
Fowl	32,400	33,500	33,900
Duck	5790	6030	6230

The average amount of cattle manure collected per head is about 18 lb per day. The total amount of animal manure produced in Myanmar can be estimated from Table 3. However, because of insufficiency and mismanagement, the actual use of manure in Myanmar is much lower than the recommended rate of manure application (i.e., 3,360 to 6,720 kg ha^{-1}).

The Introduction of Biogas Plants and Organic Recycling

Due to the high cost of fossil fuels, a program to increase the production of domestic fuels by means of biogas plants was initiated in 1974. The efficiency of gas consumption for both cooking and lighting has been improved over the last decade. The Agricultural Mechanization Department is designing a family size digester and is assessing the feasibility of using it as a suitable energy source in rural areas. The effluent from the gas plant is effectively used as organic fertilizer.

Introduction of Green Manure Practices

The most commonly used green manure plants are sunnhemp *(Crotalaria juncea)*, daincha *(Sesbania aculeata)*, cowpea *(Vigna unguiculata)*, black gram *(Vigna mungo)*, and green gram *(Vigna radiata)*.

Data from several investigations have indicated that green manure has a positive effect on crop yields, especially paddy.

Green manuring by sowing and incorporating pulses in hilly regions, especially in Shan State, not only increases the crop yield, but also effectively prevents soil erosion. The area under green manuring in Shan State amounts to about 3,240 ha.

Investigations on the use of various types of green manures, including the newly introduced stem-nodulating *Sesbania rostrata* (a West African species which grows well in standing water), are currently in progress. Although most of the green manures evaluated resulted in crop yield increases, the results do not justify their complete substitution of inorganic fertilizers. Only partial substitution of inorganic fertilizers with green manures is generally recommended.

Introduction of Biofertilizers

The nitrogen-fixing organisms which can be used as biofertilizers are:

1) *Rhizobia:* These are the best known nitrogen-fixing bacteria that associate symbioticly with legumes.
2) *Cyanobacteria (blue-green algae):* These are free living nitrogen-fixers that also have symbiotic relationships with the aquatic fern *Azolla*.

Rhizobia were used to inoculate seven different crops on a total of 63,200 ha in 1988-89. Studies comparing the effectiveness of blue-green algae and *Azolla* on rice production indicate that *Azolla* is more promising. Hence, the promotion of the use of *Azolla* is currently under consideration.

The Introduction of Improved Cropping Systems

Expanding the practice of multiple cropping has been accepted as one means of raising total crop production. The present trends in multiple cropping can be summarized as follows:

1) Growing a pre-monsoon crop before rice area (e.g., jute, cotton, and sesamum).
2) Growing some suitable crops after rice (e.g., groundnut, sunflower, peas, and beans).

3) Growing two suitable crops in succession on dryland with or without irrigation (sesamum, peas, beans, and maize).

4) Mixed sowing of two crops with different times of maturation in the same field (sesamum and pigeon peas, groundnut and maize, etc.).

The increased area under multiple cropping has been accomplished mainly through irrigation. The irrigated area as percent of the total planted area has increased from 7.5 percent in 1961-62 to 13.1 percent in 1986-87.

Future Direction of Myanmar's Agriculture

The major development objectives in the agricultural sector are:

1) To attain self-sufficiency in food for the increasing population of the country.

2) To produce sufficient raw materials to meet the requirement of agro-allied industries at home.

3) To maximize the foreign exchange earnings by expansion of our export potential for agricultural produce.

In carrying out the task of higher production in accordance with the above guidelines, the first area of consideration is to increase the production per unit area by mobilizing all available resources on selected crops in selected regions. Second is to expand production by double or multiple cropping on lands already under cultivation. Notwithstanding the need for heavy investment to bring new lands under cultivation, yearly targets are being established for this program as well. Crops under consideration for increased yields per unit area are rice, wheat, and maize for cereals; groundnut, sesamum, and sunflower for oil seeds; jute, cotton, and sugarcane for industrial crops; and chickpea, butter bean, pigeonpea, and black mungbean for food legumes.

Measures for expanding adoption of improved cropping practices and distribution of quality seeds are being undertaken to increase the crop yields and to improve crop quality.

The amounts of chemical fertilizers and pesticides distributed to farmers in Myanmar are much less than the recommended optimum rates. Therefore, the destruction of natural ecosystems and environmental pollution from excessive use of fertilizers and pesticides are not considered to be serious problems in Myanmar agriculture.

Organizational work is being carried out to increase widespread application of biofertilizers and natural fertilizers. Adoption of cropping patterns that are compatible with agroecological conditions in various regions is being encouraged for the benefit of the state as well as farmers. These measures are supplemented by organizational activities to strengthen mass participation in the implementation of agricultural development programs.

Conclusions

In addition to substantial amounts of nutrients removed from the soil by high yielding crops, natural factors causing erosion contribute to the further decline in soil fertility.

Maintaining and improving soil fertility is vital to the improvement of crop production in the agricultural sector.

Continuous use of chemical fertilizers alone may lead to the deterioration of soil structure and fertility and, consequently, of crop production. Therefore, appropriate alternatives to reduce the sole dependency on chemical fertilizers in agricultural production has been carefully explored.

Several studies on this issue have clearly indicated that various types of organic materials could augment all the plant nutrients except nitrogen, which often is a critical limiting factor. Most organic materials do not contain adequate amounts of nitrogen to sustain optimum crop yields. Hence, it would be premature to exclude the use of chemical fertilizers in any program designed to achieve increased crop production.

Since our prime target is to explore all the possible means of increasing crop production for home consumption as well as for export, we cannot as yet afford to have a drastic yield decrease which is often associated with switching over from chemical to organic farming.

Therefore, effective utilization of chemical fertilizers, combined with the systematic utilization of locally available natural resources to supplement chemical fertilizers, is still regarded as the best approach to improve crop production in the agricultural sector of Myanmar today.

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Nature Farming in India: Constraints and Prospects

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ABSTRACT. Nature has given us enough to fulfill our needs but not our greeds. In the present materialistic age, our needs include intensive farming for producing more and more to meet our demands for food, fiber, fuel, fruits, and industrial goods. Densely populated countries of the world are being forced to produce more than the sustaining capacity per unit of land permits. India, the land of Ashoka the Great Lord Buddha, was one of the most prosperous countries in the world in the ancient past. However, due to the increase in population and exploitation of resources in the past few hundred years, India has experienced a set back. Again, during the last three decades, India has emerged as a strong developing country by increasing more than threefold its food grain production from about 51 million Mg in 1950-51 to over 171 million Mg in 1988-89. Increases in the production of other essential commodities like cotton and surgarcane also have been two and threefold, respectively, during the postindependence period. No doubt we have been able to make ourselves sufficient in food grains and in other essential items but the proportionate increase in fertilizer consumption per hectare has been about a hundredfold (0.55 to 53.2 kg ha^{-1}) and twentyfold in pesticides (4000 to 80,000 Mg) during the same period. Gross irrigated area in 1951-52 was only 23 million ha and has increased to about 55 million ha in recent years. In this race for increasing agricultural production, we have learned positive and negative lessons. The problems of rising water tables in irrigated areas and increasing nutritional imbalances are evident. Perhaps the time has come when we have to stop exploitive types of farming and develop techniques for conservation/nature farming in order to sustain agricultural production and meet our demands without further degradation of our land, water, and environment. This paper reflects on the progress made by India in agriculture, with increasing use of modern technology including agrichemicals, and on the constraints and prospects of nature farming in the future.

Introduction

India is a vast country of 329 million ha and large variations in agroclimatic conditions, including the cold arid region of Ladakh with only 100 mm annual precipitation; the temperate climate of the Kashmir Valley; the subtropical alluvial plains of the northwestern region; and the tropical regions of the southern States. Rainfall varies from as low as 100 mm per annum in the Thar Desert to more than 2000 mm in certain eastern States like Assam and West Bengal. India has made tremendous progress in the last three decades, achieving a threefold growth in food grain production and almost doubling the output of other agricultural commodities. However, the need for increased agricultural production has resulted in extensive degradation of our agricultural lands, our water resources, and our environment. The purpose of this paper is to provide background information on the past and present status of agriculture in India. The concept of natural farming and its constraints and prospects for sustaining agricultural production without deteriorating natural resources are also discussed.

Past and Present Status of Agriculture in India

During the past four decades, Indian agriculture has experienced major changes. Research and development efforts have been mainly directed towards improving the production potential of individual crops and crop cultivars. With the increase in our irrigated area and introduction of high yielding varieties (HYV) during the 1960s, the production and productivity of various field crops have shown spectacular increases.

Area

As shown in Table 1, there has been a progressive increase in the total (gross) cropped area from 1951-52 to 1981-82. Increases lagged during the drought but cultivated area is expected to be more than 177 Mha during 1988-89. The major part of the total cropped area during all these periods was occupied by food grains which increased from 96.9 Mha in 1951-52 to 126.1 Mha during 1986-87. Cereals have remained the major food crop and occupy about 80 percent of the total area under cultivation. Among the cereal crops, rice grown during the kharif season (monsoon or rainy period) and wheat during the rabi season (post-monsoon or winter period) have been the major crops cultivated on about one-third and one-fourth the area under cereal crops, respectively.

The data in Table 2 further reveal a trend of change in area under different crops during the past 35 years. The area under rice increased 50 percent from 29.8 Mha in 1951 to 40.7 Mha in 1986-87, while the wheat area more than doubled from about 9.5 Mha in 1951-52 to 22.8 Mha in 1986-87. The total area under cereals also increased during this time, as shown in Table 2.

Table 1. All India Cultivated Area (Fertilizer Statistics, 1987-88).

Year	Area Sown Gross	Net	More Than Once	Cropping Intensity
	Mha			%
1951-52	133	119	13.8	112
1961-62	156	135	20.8	115
1971-72	165	140	25.1	117
1981-82	177	142	35.0	125

Table 2. Gross Area Under Important Crops in India (Fertilizer Statistics, 1987-88).

Year	Rice	Wheat	Total Cereals	Total Pulses	Total Food Grains	Total Oil Seeds	Cotton	Sugar-cane
	Mha							
1951-52	29.8	9.5	78.2	18.8	96.9	11.6	6.5	1.9
1961-62	34.7	13.5	93	24.2	117	14.8	7.9	2.4
1971-72	37.7	19.1	100	22.1	122	17.2	7.8	2.4
1981-82	40.7	22.1	105	23.8	129	18.9	8.1	3.2
1986-87	40.7	22.8	103	23.1	126	18.7	7.1	3.1

On the other hand, the area under pulses registered only a small increase from 18.8 Mha in 1951-52 to 24.2 Mha in 1961-62, and decreased to 23.1 Mha in 1986-87. The area under oilseeds increased more rapidly up to 1971-72 but remained almost constant during later years. Although cotton has been an important crop since the preindependence days, the area under this crop did not increase significantly. The area planted to cotton increased from 6.5 Mha in 1951-52 to about 8.1 Mha in 1981-82, but had decreased by 1986-87. The area planted to sugarcane increased 50 percent from 1950-51 to 1986-87.

Productivity and Production of Important Crops

Looking to the average yield figures given in Table 3, it is highly satisfying to note that there has been definite growth in the yields of almost all the crops. This is mainly attributable to increases in irrigated area and fertilizer consumption, the use of high yielding varieties (HYV), better production technology, more efficient management practices, the identification of suitable crops for dryland areas, and conservation of rainfall in these areas. The largest increases in productivity were achieved with rice, wheat and other cereal crops. Total cereal production doubled during this overall period.

Cereals and millets are responsive to irrigation and high levels of inputs and management. Data in Table 4 indicate an increase in India's irrigated area from 17 percent of the overall cropped area to more than 30 percent from 1951 through 1987. During this same period, the use of fertilizers (Table 5), in terms of NPK, increased about 100 times from 0.55 kg ha^{-1} to about 53.2 kg ha^{-1}. These inputs went largely to the cultivation of rice, wheat, sugarcane, cotton, and to some extent to high yielding varieties of maize, pearl millet, and sorghum grown under irrigated conditions. Total production of cereal crops has also shown an upward trend due to increases in area planted and productivity of crops (Table 6). Rice production increased by about threefold, from in 1951-52 to 1986-87. A more dramatic increase occurred in wheat production. The total output of wheat in India increased from only 6.1 million Mg in 1951-52 to 45.5 million Mg in 1986-87. The increase in total output of cereal crops more than doubled during this period.

Productivity of pulses, oilseeds and cotton did not show encouraging trends even though these crops have received considerable production emphasis by researchers, government departments, and other development agencies. Average yield of pulses (Table 3) increased

Table 3. Productivity of Important Crops in India
(FertilizerStatistics, 1987-88).

Year	Rice	Wheat	Total Cereals	Total Pulses	Total Food Grains	Total Oil Seeds	Cotton	Sugar-cane (cane)
	....	....	....	.... kg ha^{-1}	....	....	....	....
1951-52	714	653	557	448	536	430	85	31,800
1961-62	1030	890	763	485	705	493	100	42,300
1971-72	1140	1380	936	501	858	526	151	47,500
1981-82	1310	1690	1160	483	1030	639	166	53,800
1986-87	1483	1998	1284	508	1140	613	167	59,700

Table 4. All India Irrigated Area (Fertilizer Statistics, 1987-88).

Year	Irrigated Area Gross	Net	Percent of Total Cropped Area
	.... *Mha*		%
1951-52	23.2	21.0	17.4
1961-62	28.4	24.8	18.2
1971-72	38.4	31.5	23.3
1981-82	51.5	39.9	29.1
1984-85	54.1	41.8	30.7

Table 5. All India Consumption of Plant Nutrients Per Unit of Gross Cropped Area (Fertilizer Statistics, 1987-88).

Year	Gross Cropped Area	Consumption N	P_2O_5	K_2O	Total Consumption
	Mha		*kg ha*$^{-1}$		*Mg X10*^{6}
1951-52	133	0.44	0.05	0.06	0.06
1961-62	156	1.6	0.39	0.18	0.34
1971-72	165	10.4	3.38	1.88	2.65
1981-82	177	23.0	7.47	3.82	6.06
1987-88	176	36.1	12.3	4.80	9.01

slightly. In the case of oilseed crops, the average yield increased from 430 kg ha^{-1} in 1951-52 to over 600 kg ha^{-1} at present. Similarly, the production of pulse crops (Table 6) tripled during the 1950s but then remained stagnant.

The initial productivity level of cotton, as seen in Table 3, was very low but has improved. The total production of this crop in India doubled during this period, from 3.3 million bales in 1951-52 to 7.0 million bales in 1986-87.

Productivity of sugarcane has also increased twofold during the last three decades, from 32 Mg cane ha^{-1} to about 60 Mg ha^{-1}. Total production of sugarcane has increased threefold during this period (Table 6).

Table 6. Total Production of Important Crops in India
(Fertilizer Statistics, 1987-88).

Year	Rice	Wheat	Total Cereals	Total Pulses	Total Food Grains	Total Oil Seeds	Sugar-cane	Cotton Bales
	....	....	....	........Mg X10^6	....	....	....	X10^6
1951-52	21.3	6.1	48.6	3.4	51.9	5.0	61.6	3.3
1961-62	35.6	12.1	70.9	11.7	82.7	7.3	104	4.8
1971-72	43.1	26.9	94.1	11.1	105	9.1	114	6.9
1981-82	53.2	37.4	122	11.5	133	12.1	186	7.9
1986-87	60.4	45.5	132	11.7	144	11.4	182	7.0

Cropping Intensity and Area Under Cereals and Pulses

There has been a shift in the type of crops, crop rotations, and cropping intensity in different regions of India during the past 35 years. It is absolutely necessary that we increase our productivity and production on existing lands since there is little additional land that is either available or suitable for cultivation. Irrigation has allowed cropping intensity to increase, and there is now considerable potential to grow more than two crops in a year on the same piece of land. Similarly, under dryland conditions, new technologies have made it possible to grow at least one short duration crop even under very limited soil moisture. All these factors resulted in higher cropping intensity, from about 111 percent in 1951-52 to 125 percent in the 1980s (Table 1).

Fertilizer Use

At the time of independence, the level of fertilizer consumption in India was almost negligible and during 1951-52 only about 60,000 Mg of NPK fertilizers were used (Table 5). The growth in fertilizer use has been phenomenal during the past 35 years. Fertilizer consumption has increased from 0.34 million Mg in the early 1960s to 9.01 million Mg in 1987-88.

Consumption per hectare increased a hundredfold from 0.55 kg ha^{-1} in 1951-52 to 53.2 kg ha^{-1} in 1987-88.

Pesticides

Control of weeds, insects, pests, and diseases is essential for attaining an optimum level of productivity and production, particularly with HYV of field, vegetable, and fruit crops. Although the level of pesticide application in India during the last three decades has been lower than that of the developed countries, the use of these chemicals has increased by 20 times, from a level of 4000 Mg in 1954-55 to 80,000 Mg in 1986-87. Insecticides have comprised about 75 percent of total pesticides used in the country. However, during the last two decades with changes in crop rotations and associated weed problems, the use of herbicides has increased rapidly.

Irrigation

After independence, the main efforts of the Government of India and the various State Governments have been aimed at bringing land under irrigation. Thus, there has been a rapid increase in the gross as well as the net irrigated area in the country during the last 35 years (Table 4). The gross irrigated area increased from 23.2 Mha in 1951-52 to 54.1 Mha in 1984-85 and the proportion of irrigated area to total cropped area increased from 17.4 percent in 1951-52 to more than 30 percent in 1984-85.

Constraints and Problems

As discussed earlier, there has been a substantial increase in the irrigated area, which has resulted in increased crop production through the use of high yielding varieties, fertilizers, and agricultural chemicals. In many cases, double- and triple-cropping have been possible with appropriate inputs. While crop production and productivity have increased from these agrichemical inputs, the potential for environmental pollution has also increased. As pollutants, these chemicals can lead to the degradation of soil health and soil productivity by adversely affecting the physical, chemical, and biological properties of soil. The excessive use of agrichemicals can also impair both surface and ground water quality and cause possibly adverse effects on human and animal health.

Soil Degradation

The increased productivity of field crops during the last three decades, particularly wheat and rice, has been due largely to the increase in irrigation and fertilizer use. However, increased cropping intensity has often resulted in soil degradation through erosion and nutrient depletion. Indian soils were once only deficient in N, but now most of our soils are also deficient in P and K. Moreover, soils utilized for cereal-based crop rotations are becoming deficient in micronutrients as well. The best example may be for the rice-wheat crop rotation in northwest India. In this entire belt, zinc was not a limiting factor for plant growth up to 1970. But with the use of HYVs of rice and wheat in the same crop rotation with increased N and P fertilizers, soils have become deficient in zinc. Consequently, there is now a blanket recommendation for the application of 25 kg $ZnSO_4$ ha^{-1} to these soils. In some other areas, sulphur, iron, and other elements are limiting plant growth and yield because of intensive cultivation of high yielding crops and varieties under irrigated conditions.

Soil Sickness

Continuous use of high levels of fertilizers and adoption of exploitive agricultural practices associated with cereal-based rotations, have resulted in a decline in crop yield and crop quality. The exact reason for this is not known. However, soil sickness is becoming a major cause of concern in these intensively cultivated, irrigated lands.

Table 7 shows that out of a total geographical area of 329 Mha, about 150 Mha has been subject to wind and water erosion. About 25 Mha has undergone severe degradation due to an exploitive type of agriculture. Excessive and improper irrigation have created both low and high water table problems. In areas having good quality water in northwest India, tubewells are the major source of irrigation, and the lowering of the water table has become a very serious problem.

On the other hand, in areas having brackish water along with canal irrigation, water tables have been rising at a rate of about 50 to 60 cm per year and have caused increased salinization and loss of soil productivity.

The irrigated belt of semiarid northwest India is facing this problem on a large scale. Table 7 reveals the extent of such problems as salinity, alkalinity, waterlogging, ravines,

Table 7. Problems of Soil Erosion and Land Degradation in India
(Fertilizer Statistics, 1987-88).

Soil Problem	Area
	Mha
1. Total geographical area	329
2. Area subject to water and wind erosion	150
3. Area degraded through special problems	25.0
a) Water logged	6.00
b) Alkaline soil	2.50
c) Saline soil including coastal sandy areas	5.50
d) Ravines and gullies	3.90
e) Area subject to shifting cultivation	4.36
f) Riverine and torrents	2.73
4. Total problem area	175
5. Annual average loss of nutrients from degraded land	5.37 to 8.40 Mg $X10^6$
6. Average loss of production for not developing ravines	3 Mg
7. Average annual rate of encroachment of table lands by ravines	8000 ha
8. Total flood prone area	40 Mha
a) Average area affected by floods	9 Mha
b) Average cropped area affected by floods	3.8 Mha
9. Total drought prone area	260 Mha
10. Additional land needed in 2000 A.D.	60 Mha
a) For crop production	10 Mha
b) For production of fuel wood	40 Mha
c) For production of fodder	10 Mha

and gullies which have led to the removal of these lands from agricultural production. Although there have been many efforts to reclaim these lands, the input costs for the rehabilitation and restoration of productivity are economically prohibitive in most cases.

Soil Nutrients and Organic Matter

The end result of intensive and exploitive agriculture during the last three decades has been accelerated soil erosion, loss of soil fertility, and depletion of soil organic matter. The data for 1987-88 (Table 7) indicate that the average loss of nutrients due to soil degradation and erosion was between 5.37 to 8.40 million Mg per year. Similarly, the average annual requirement for major plant nutrients (NPK) at the present level of food production is about 7.5 million Mg for cereal crops, while the addition of chemical fertilizers to all crops is less than 3.0 million Mg (based on 37, 14 and 44 percent use efficiency of added N, P and K, respectively). These figures are alarming since they indicate such wide differences between the depletion and addition of these nutrients in Indian soils. Another important damaging effect of intensive cropping has been on the organic matter content of the soil. The results of a long fertility trial conducted at Haryana Agricultural University, Hisar, indicate that the organic carbon content in unfertilized soil has declined to about half of the initial level. Similarly, N added through chemical fertilizers did not result in an increase of organic carbon; however, when farmyard manure was used, the soil organic carbon content increased to about twice the initial level.

Soil Pollution

Little is known of the effects of pesticides on the soil microflora which include some of the most important nontarget organisms threatened by man's mismanagement of the ecosystem. These organisms produce antibiotics and other metabolites; control organic matter transformations; decompose organic wastes and add nitrogen to the soil; decompose pesticides; transform rocks and other inorganic matter to provide nutrients and increase soil tilth; act as growth factors for plants and animals; keep the soil microecosystem in balance; and help to integrate living and nonliving factors of the environment.

A study by Malkomes (1976) on the effects of applied herbicides on the soil microflora and fauna indicate that the application of methabenzthiazuron stimulated the population of actinomycetes and algae but did not affect other microorganisms, and had little effect on straw decomposition (Table 8). Dichlorprop, another herbicide, increased soil dehydrogenase activity during the entire growing season. This herbicide stimulates bacterial and algal populations but reduces the numbers of fungi and actinomycetes (Malkomes, 1976).

Sarawad (1985) reported that thimet (phorate), bavistin (carbendazim) and diuron at 10 to 100 ppm inhibited nitrification, but soil dehydrogenase activity was stimulated by all pesticides. While some stimulatory responses by soil microorganisms can occur at relatively low concentrations of pesticides, the response to higher concentrations, and particularly at increased time of exposure, is almost inhibitory.

A major source of soil pollution is from the use of polluted water, such as municipal sewage and industrial effluents, for growing vegetable and fodder crops. Irrigation with such polluted water sources can result in the accumulation of heavy metals that can cause phytotoxicity in crops and endanger the human food chain. Continued use of such wastewaters can adversely affect the physico-chemical properties of agricultural soils and decrease their productivity (Narwal et al., 1988).

Table 8. Microbial Populations as Affected by Herbicides Malkomes, 1976).†

Microorganism	Control	Dichlorprop	Methabenzthiazuron
Bacteria	100	381	103
Actinomycetes	100	71	150
Fungus	100	38	138
Algae	100	182	212

† Population estimates were made four days after treatment.

Nature Farming for Conserving Soil and Protecting the Environment

In the postindependence period, with the increasing use of agrichemicals and supplemental irrigation, we have increased our wheat production sevenfold. Wheat is mainly an irrigated crop and a major food grain grown in India. However, the problems of lowering water tables in areas having good quality ground water, and the rising water tables that have caused serious soil salinity problems in areas having brackish ground water, have posed a major threat to sustainable agricultural production. Similarly, widespread soil deficiencies of phosphorus, zinc, and more recently sulphur and iron have been detected in areas of intensive irrigated farming. In these areas the use of high analysis nitrogenous fertilizers is posing a problem of unbalanced nutrition in crops and of malnutrition of farm animals. Although we have not yet reached a high consumption level of pesticides, the hazards of pesticide pollution is now being reported in certain areas. With this in mind, and in view of our future need for increased agricultural production, we must adopt the principle of nature farming to sustain our needs for food and fiber, to conserve our natural resource base, and to protect the environment. The development of integrated farming systems that are stable, productive, economically-viable, and environmentally sound over the long-term will be absolutely essential to ensure our future health and prosperity.

Although there may be several components to achieve this goal, some of the important ones are:

1) Recycling of farm residues/by-products/organic wastes;
2) Crop rotations;
3) Green manuring;
4) Use of soil amendments;
5) Biological/mechanical control of weeds, insects and diseases;
6) Energy conservation; and
7) Integrated farming systems.

Recycling of Farm Residues, By-Products and Organic Wastes

The projected demand for food grains in India for the year 2000 A.D. has been estimated at 225 million Mg (Randhawa and Abrol, 1990). Such a high level of production can be attained only through improved management of different inputs including fertilizers. However, this requires careful study of certain technological and economic considerations, such as the nutrient requirement of crops; fertilizer use on crop production; economics of using large quantities of fertilizers; and their overall effect on environmental pollution. Quantification of crop response to fertilizers in various countries of the world has shown that there is a significant relationship between fertilizer use and the yield of most crops. The NPK fertilizer consumption in India in 1985-86 was only 50.3 kg ha^{-1} per year compared with 346 kg ha^{-1} in the Netherlands, 380 kg ha^{-1} in Japan, and 378 kg ha^{-1} in the Republic of Korea. The corresponding yield figures for major cereals were 1560, 6160, 5850 and 5650 kg ha^{-1} in India, the Netherlands, Japan, and the Republic of Korea, respectively (Fertilizer Statistics, 1986-87). Indian scientists have established that, with balanced fertilization, yields of 4000 to 5000 kg ha^{-1} of wheat and rice can be obtained even on farmer's fields. At the macro-level, to obtain 5000 kg of wheat from one hectare, the average uptake of N, P_2O_5, and K_2O is about 125, 40, and 105 kg ha^{-1}, and for 50,000 kg of rice yield, the uptake will be about 106, 39, and 112 kg ha^{-1} N, P_2O_5, and K_2O, respectively (Singh et al., 1988).

It has been estimated that about 50 percent of the nutrient requirement to grow a crop of wheat or rice can be met by soil reserves. Moreover, in view of the percent use efficiency of applied fertilizers (i.e., 37, 14, and 44 percent of applied N, P, and K, respectively) the fertilizer requirement for pulses, fibre, oilseeds, other major crops, and vegetables will further increase the required quantities of fertilizer nutrients. Taking the above facts on cereal-based food grains production and fertilizer use efficiency in India into consideration, the quantity of N, P_2O_5, and K_2O required to meet our target of 225 million Mg of food grain production by the year 2000 will be about 6.0, 6.0, and 5.5 million Mg, respectively (Singh et al., 1988). The present total N, P_2O_5, and K_2O consumption is 9.0 million Mg. Fertilizers will also be required for the production of other nonfood grain crops.

It is virtually impossible to meet these calculated fertilizer requirements because of energy costs, lack of production capacity, and lack of foreign exchange. Thus, to maintain even the present level of soil fertility and to keep pace with food production for a rapidly growing population, we must focus on integrated nutrient management involving: (1) the collection, treatment, and utilization of urban wastes for crop production and environmental conservation; (2) increasing biological N fixation through inclusion of legumes in cropping systems and cultivation of shrubs and trees along the bunds; and (3) increasing the efficiency of applied fertilizers through better management practices.

Crop Rotations

Emphasis in the past has been on developing cropping systems (both intercrop and sequential) to ensure stable/optimal yields and maximum profits. At the same time, full exploitation of the agroclimatic resources should be the main objective. The superiority of crop rotations over monocropping has been thoroughly documented throughout the country. Research results have shown that the inclusion of leguminous crops can provide 40 to 50 kg N ha^{-1} for cereal crops such as wheat, rice, pearl millet, and sorghum. With the adoption of a rice-wheat rotation in northwest India, the problem of grassy weeds has posed a serious constraint to stabilizing crop yields without chemical weed control. However, the inclusion of other crops in the rotation such as sugarcane, potato, and mustard has facilitated nonchemical weed control, and the net return from these crops was actually higher than from cereal crops.

Intercropping and mixed cropping has been practiced in India for many years, but because of increased food needs such practices were abandoned in favor of monocropping. However, research has shown that even with HYVs this practice, especially under dryland or rainfed conditions, was more profitable and more conserving of soil fertility than monocropping. Inclusion of crops like pigeonpea with sorghum and pearl millet, and soybean with maize can yield about 90 percent of a sole sorghum or maize crop and about 50 percent of sole pigeonpea or soybean.

Green Manuring

Rice-wheat has emerged as an important rotation in the irrigated areas of northwest India. This is a highly productive but very exhaustive rotation. Experiments conducted in Haryana and Punjab have shown that inclusion of cowpea or sesbania as a green manure crop after harvesting wheat in April, and before transplanting rice at the end of June, resulted in rice yields of 40 to 50 kg ha^{-1}, and also helped to maintain good soil tilth. Because of increased pressure on the land for food production, we cannot afford to replace any main season crop with a green manure crop; however, a green manure crop could be included in the interval between two main crop seasons. This practice needs further assessment.

Soil Amendments

According to recent reports, the availability of plant nutrients from urban wastes alone accounts for 30,000 Mg of N, 21,000 Mg of P_2O_5, and 30,000 Mg of K_2O. The corresponding values from rural wastes account for 1.23 million Mg of N, 0.67 Mg of K_2O, respectively. Little attention, however, has been given to collection and treatment of sewage from towns and cities, and its utilization for agricultural purposes. Research at various agricultural institutes in the country have shown that both rural and urban organic wastes are highly valuable commodities for restoring and maintaining the tilth, fertility, and productivity of agricultural lands.

Under the subtropical and semiarid conditions in India, it has been shown that over a span of 20 years the organic carbon content of agricultural soils was reduced to 50 percent of its original value where no farm yard manure (FYM) was added in the cereal-based cropping system. The addition of 15 Mg of FYM ha^{-1} could increase the organic carbon content from 0.47 percent to 0.56 percent, or by 19 percent, whereas addition of 45 Mg of FYM ha^{-1} increased the organic carbon content by more than 50 percent of its original value. It is noteworthy that the addition of FYM in conjunction with chemical fertilizer has not only increased the soil organic carbon content, but has also resulted in significantly higher yields than from either treatment applied alone.

The introduction of irrigation in areas having brackish underground water has created problems of rising water tables and soil salinity/alkalinity. To overcome soil alkalinity due to brackish water, regular additions of gypsum must be made to maintain crop yields and soil productivity.

Biological and Mechanical Control of Weeds, Insects, and Diseases

Aquatic, terrestrial, and parasitic weeds cause enormous direct and indirect losses to the ecosystem as a whole. Losses caused by various types of weeds in different agricultural crops can, however, be minimized by timely and careful application of herbicides. At the same time, their continuous and indiscriminate use can pollute our land, water, and atmosphere. For example, in some locations where intensive vegetable production and rice farming is being practiced, there is some evidence of environmental pollution by pesticides. Suppression of weeds through biotic agents, mechanical cultivation, and proper crop rotation should be an important component of our crop production plan. Biological control of Prickly pear *(Oputina spp.)* was first achieved in India when *Dactycopins ceylonicus* was introduced from Brazil in 1795. More work in this area could be usefully undertaken.

Grassy weeds such as wild canary grass can be controlled by following a sugarcane-based, three-year crop rotation. Similarly, by using special planting techniques and row crop orientation, broad-leaved weeds can be controlled more readily. Biological methods for control of *Pyrilla* in sugarcane have almost eliminated the use of pesticides for control of this pest in many parts of India. Research is underway to develop effective biological control methods for serious pests like pinkboll worm in cotton and aphids in mustard.

Water and Energy Conservation

Water is essential for crop production and its proper use must be ensured. With total development of our water resources we could bring about 32 percent of our cultivated area under irrigation. At the same time, intensification of land use through irrigation can be self defeating, because it is exploitive and often results in the degradation of our soil and water resources. Thus, management strategies are urgently needed that will effectively conserve and utilize natural rainfall and maintain soil productivity. In rainfed agriculture the only source of available water is the rainfall on a given area. Runoff, erosion, and drainage pose serious problems for most semiarid areas in India. It is not unusual to experience excessive rainfall and serious drought during the same growing season. Methods and strategies for the collection and conservation of runoff water and its utilization for rainfed agriculture have been developed under the All India Coordinated Research Project on Watershed Management. A watershed approach to the harvesting and utilization of water is currently being followed in many of the dryland areas. Similarly, in areas with brackish ground water, we have to practice saline agriculture. Instead of introducing canal water to these problematic areas we have to survive with saline agriculture so that the natural hydrology is not disturbed.

Agriculture is a great consumer of energy and is in competition with industry. Presently, agriculture is one of the largest consumers of solar energy. We in India are fortunate to have such a geographical location where abundant solar radiation is available throughout the year. Research in many advanced countries, and India as well, have shown that solar energy can be conserved, stored, and utilized for commercial purposes. Increased use of biogas not only provides a major source of fuel for agriculture, but also facilitates the recycling of a large quantity of plant nutrients. Wind is another alternative energy source in semiarid parts of the country and efforts to utilize wind energy are already underway. While directing our efforts towards the search for alternative energy sources, our motto in energy consumption, either in agriculture or industry, should be "energy conserved is energy saved."

Integrated Farming Approach

Conceptually, integrated farming involves a mix of crops, animals, poultry, fish, and agroforestry. It follows the concept of conservation and recycling of energy and nutrients in the soil-water-plant-atmosphere continuum. Animal feeding trials and metabolic studies conducted at Haryana Agricultural University, Hisar, India and elsewhere have conclusively shown that only 25 percent of the nutrients and energy fed to ruminant animals is retained in their bodies while 75 percent is recycled in the continuum. Thus, it is essential that animal wastes be recycled efficiently and effectively for the greatest agricultural benefit, and to ensure that they do not become environmental pollutants. In view of the increased population pressure on land, and the increased demand for food and fiber, India must increase its agricultural production and productivity per unit of land, but with utmost concern for conserving the natural resourse base and protecting the environment. The development of a more sustainable agriculture, can best be achieved through an integrated farming approach.

Research Needs and Priorities

To produce more food, our efforts to date have been directed toward the development of high yielding and high input responsive crop cultivars, particularly cereals. Recently there has been a growing consensus that India should shift toward a cropping systems or farming systems approach. To maintain good soil quality and a pollution-free environment, we need to begin solving the problems of soil fertility, crop nutrition, plant diseases, insect and weed control, renewable energy sources, and efficient utilization of natural precipitation.

To produce enough food to feed the Indian population by the year 2000, and to avoid further depletion of our soil fertility status, the projected plant nutrient requirement will be about 18 million Mg compared with the current consumption level of about 9 million Mg. Therefore, it is essential that research be directed toward the development of efficient strains of nitrogen-fixing bacteria for food legumes and green manure crops. Programs for collecting, treating, and processing urban and industrial organic wastes for beneficial use on agricultural land should be a high priority for state and local governments. Such materials as lawn clippings, slaughterhouse wastes, sewage, nightsoil, wood processing wastes, and street refuse could be composted into valuable organic amendments and biofertilizers. Thus, it is necessary that we shift from an individualistic approach to crop nutrition toward a system of integrated nutrient supply and management in which crop rotations, organic recycling, biological nitrogen fixation, and biofertilizers are supplemented and balanced with chemical fertilizers to achieve long-term, sustainable agricultural production.

Some African and Asian countries are now facing a serious problem of protein malnutrition known as kwashiorkor. Research is needed to improve the nutritive value and digestibility of soybean and groundnut flour for human consumption. Thus, it is not only important to increase agricultural production but also to enhance the nutritional value of agricultural commodities thorugh improved processing methods.

Efforts to control insect pests and weeds, particularly in developing countries, have been on an individualistic basis and no serious efforts have been made toward integrated pest management. A suitable mix of crop rotations, and cultural, mechanical, and biological control of pests should reduce the need for pesticides, minimize environmental risks, and lower farm production costs.

Conclusions

India has made unparalleled progress in agriculture during its postindependence period by increasing food grain production from about 51 million Mg to 171 million Mg, doubling the production of cotton, and increasing sugar production threefold. However, there are certain problems which must be dealt with to ensure our future prosperity. Nature farming, with its increased emphasis on conservation of natural resources and protection of the environment, seems to hold considerable promise for achieving desirable and feasible solutions to these problems. High priorities for research and technology transfer include the following:

1) Efficient use of water with increased emphasis on rain water harvesting.
2) Control rising water tables in canal irrigated areas of arid and semiarid regions having brackish ground water.
3) Develop salt-, drought-, and pest-tolerant varieties of field, vegetable and fruit crops.
4) Integrated nutrient management.
5) Integrated pest management.
6) Identification of efficient crop zones and adoption of efficient cropping systems.
7) Develop information on integrated farming systems for different agroecological situations.
8) Develop suitable marketing and processing infrastructure for preserving/processing of surplus produce.
9) Improve the nutritional value of agricultural by-products with particular reference to protein nutrition.
10) Strengthen research-extension linkages to ensure rapid adoption of conservation farming practices.

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Agroecological and Socioeconomic Environment of Northeast Thailand

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ABSTRACT. The Northeast Region comprises approximately one-third of the total area of Thailand, and about 17 million people or about one-third of the total population. Farmers practice a subsistence type of agriculture that is dominated by rainfed, rice-based cropping systems. Agricultural production and per capita income from agriculture are the lowest in the country. This can be attributed to a number of factors including marginal, infertile, and sandy soils; erratic and inadequate rainfall; lack of irrigation development; obsolete farming methods; lack of mixed cropping; low quality livestock; and unstable market conditions. Collectively, these pose major problems to any attempts at rehabilitation of the Northeast. A logical starting place is to initiate research and demonstration programs to improve soil productivity and farming methods. The key to improving soil productivity is through regular additions of organic amendments. This would help to overcome the extreme soil chemical and physical properties that now contribute to low crop yields.

Introduction

Northeast Thailand is comprised of 17 provinces with an area of approximately 170,000 km^2 or 33 percent of the total area of Thailand. It is bound by Laos in the north and in the east; by Kampuchea in the east and south; and by the lower part of North Thailand in the west (Figure 1). The Northeast Region consists mainly of a shallow undulating plateau known as the Korat Plateau with an average elevation of approximately 100 to 200 m above sea level. It is underlain by salt bearing rocks that have contributed to a serious problem of soil salinity. The Northeast is an economically depressed area because of its low level of agricultural production and its low per capita income compared with the rest of the country.

The Physical Environment

Topography

As shown in Figure 2, Northeast Thailand is bound on the west by the Phetchabun Mountain Range and on the south by the San Kam Pang and Dangrek Mountain Ranges. The Phu Phan Mountains run in a northwest to southwest direction which divides the region into the Korat and Sakon Nakon Basins.

The Korat Basin includes a large part of a plain known as Tung Kula Rong Hai, an area of 336,000 ha. This plain includes five provinces and is the major rice growing area of the region.

The Sakon Nakon Basin comprises the northern part of the Northeast Region and includes Sakon Nakon, Mukdahan, Nakon Phanom, Nong Khai, Udon Thani, and Loei Provinces. The area is influenced by tropical cyclones which originate over the South China Sea, resulting in high levels of rainfall.

Rivers

The Chi and Mun Rivers are the two main rivers of the Northeast Region (Figure 3). The Mun River originates from the Sun Kam Pang Mountains in Nakon Ratchasima and flows through Buriram, Surin, Roi-Et, Srisaket and finally into the Mekong River in Ubon Ratchathani Province.

The Chi River originates from the Phetchabun Range in Chaiyaphum Province and runs through Khon Kaen, Maha Sarakham, Kalasin, Roi-Et, and Yasothon before meeting with the Mun River in Ubon Rachathani and then flowing into the Mekong River.

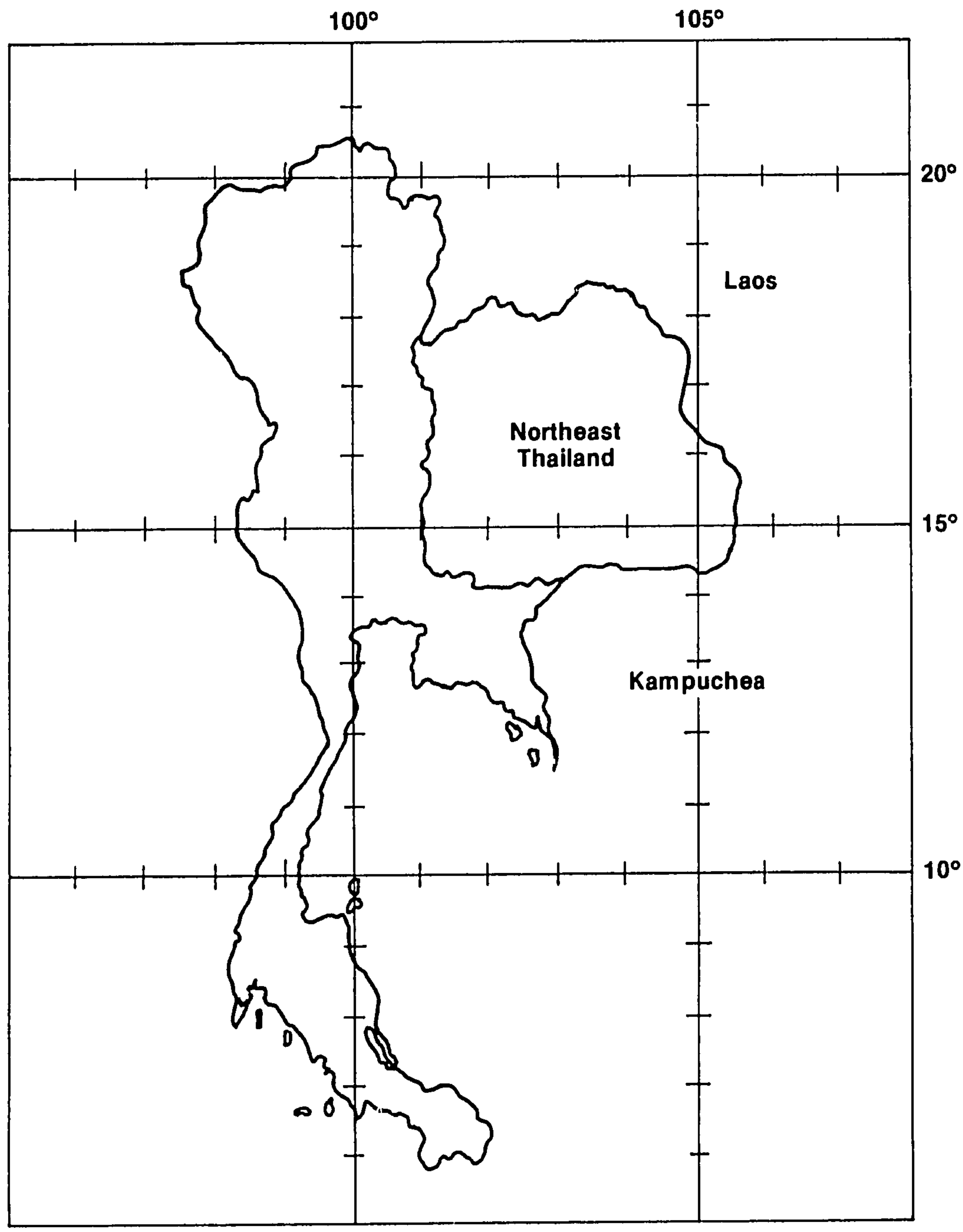

Figure 1. Map of Thailand Showing the Northeast Region.

Climate

The climate of the Northeast Region can be described as a tropical savanna climate. Its average annual temperature is 18 °C. There are three seasons: the rainy season from the middle of May to the end of October, the cold season from November to the middle of February, and the hot season from February to the middle of May. The region is dominated by tropical cyclones which originate over the South China Sea, resulting in high levels of rainfall which average 1400 mm per year. However, the distribution of rainfall is

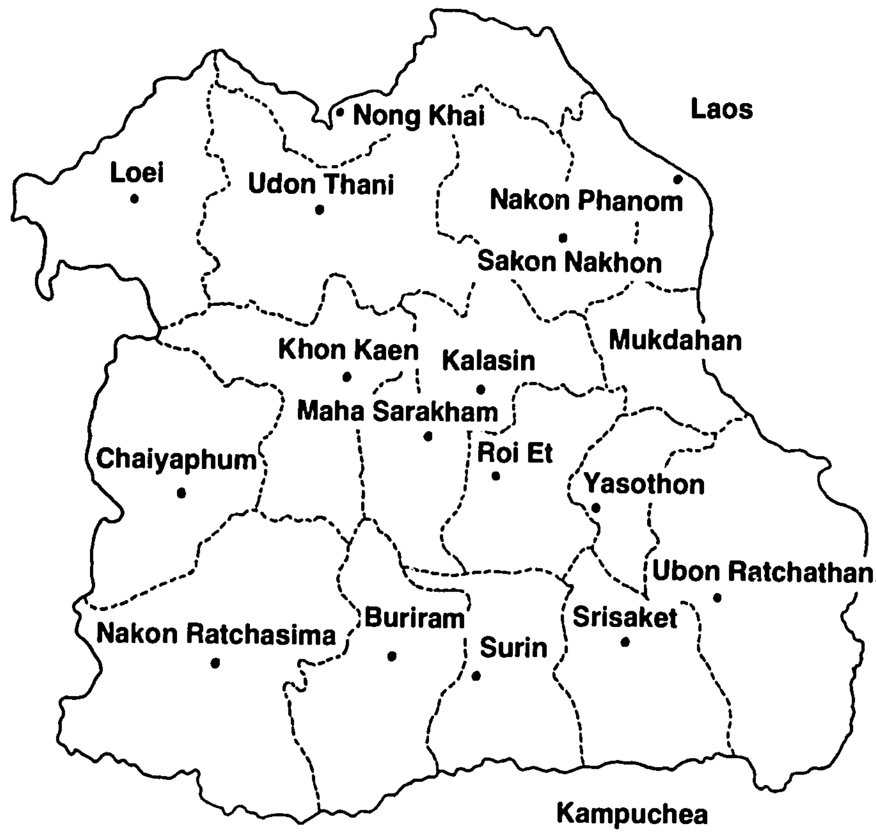

Figure 2. The Northeast Region Showing Changwat (Provincial) Boundaries.

uneven. Eighty percent of the total rainfall occurs in the months of August and September and is accompanied by excessive runoff into the Mun and Chi Rivers and finally into the Mekong. This is due to the low water holding capacity of the soils in the Northeast Region.

Soils

Most soils of the Northeast are sandy loams and loamy sands. They are very low in fertility, low in water-holding capacity, often highly acidic, and low in their organic matter content. With the exception of Loei Province, the region is underlain by salt bearing rocks giving rise to salinity problems that have affected 2.85 Mha of paddy. This has resulted in a loss of soil productivity and decreased rice production compared with other regions.

Forestry

Excessive deforestation from logging and land clearing continues to be a serious problem in Northeast Thailand as well as in other regions. There is only about 24,000 km^2 of forest land left in the Northeast, or 15 percent of the total land area. Important types of forests found in the mountainous areas of the Northeast include tropical evergreen, mixed deciduous, and scrub forests.

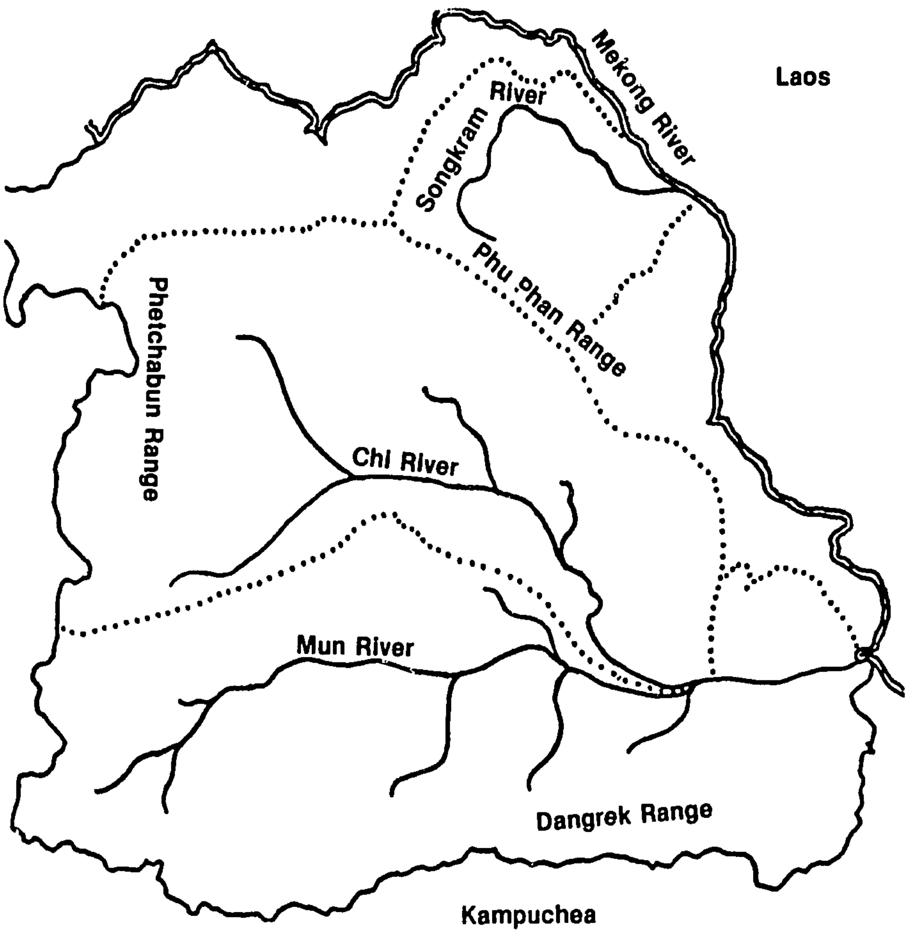

Figure 3. Topography of Northeast Thailand.

Mineral and Energy Resources

Important minerals found in the Northeast include copper, manganese, lead, potassium, and natural gas. Potassium which is needed as a fertilizer is found in 14 provinces of the region covering approximately 50,000 km^2.

Population and Manpower

The 1984 data obtained from the Department of Local Administration, Ministry of the Interior, reveals that the population of the Northeast is more than 17 million or about 35 percent of the total country. The annual rate of population increase is 2.15 percent. The average household size is 5.7 people. The population density averages about 100 people per km^2. The labor population is approximately 8.5 million or 48 percent of the total population of the Northeast Region. More than 96 percent of the people live in rural areas or on the outskirts of towns. The remaining 4 percent live in the municipal areas.

Land Use

According to the Agricultural Economics Division, Ministry of Agriculture and Cooperatives, in the 1985-1986 cropping year the land used for agricultural purposes was about 8 Mha or slightly less than one-half the total land area. The land use categories are listed in Table 1 by area and percentage of use. It is readily apparent that rice-based cropping systems are predominant in the Northeast with some 35 percent of the total land area devoted to paddy.

Table 1. Land Use in the Northeast During the 1985-1986 Cropping Year.

Land Use	Area	Area Used
	ha	%
Paddy	5,930,000	35.1
Field Crops	1,890,000	11.2
Fruit Crops	104,000	0.62
Horticulture	16,700	0.10
Pastures	70,800	0.42
Idle	354,000	2.09
Forest	2,480,000	14.7
Dwellings	169,000	1.00
Others	124,000	0.73
Unclassified	5,760,000	34.1
Total†	16,800,000	100

† Totals may not be precise due to rounding.

Land for Agricultural Use and Land Holdings

Approximately 8.65 Mha, or 52 percent of the total area, are used for agriculture in the Northeast Region. The average farm size is 4.32 ha. Farms in Nakon Ratchasima Province average some 5.76 ha per unit, which is the highest for the region. Farmers in Mukdahan, however, own the least amount of land, only 2.8 ha per household. More than 90 percent of the land devoted to agriculture is owned by farmers. The rest is either rented, mortgaged, or used without rental payment.

Economic and Social Environment

The economic output of the Northeast is 42 percent for agricultural products and 58 percent for non-agricultural products. The largest part of the total income of the people in this region is derived from the cultivation of crops such as rice, cassava, sugarcane, kenaf, maize, and cotton. These crops account for 80 percent of the total agricultural revenues of the region. Minor crops include mungbean, soybean, groundnut, castorbean, sesame, and vegetables.

Data from the Agricultural Economics Division, Ministry of Agriculture and Cooperatives, show that the income from non-agricultural products was 6 to 7 times greater than that from agricultural products (Table 2).

The Northeast is recognized as an economically depressed area where the average annual per capita income in 1983 was the lowest in Thailand, that is, 7,146 Baht or $265 U.S. (Table 3). This is only 38 percent of the average annual per capita income for the country as a whole.

Table 2. Per Capita Income in the Northeast Region from Agricultural Products and Non-Agricultural Products During 1981-1984 (Baht Currency).†

Year	Per Capita Income from Agricultural Products	Per Capita Income from Non-agricultural Products	Ratio of Income from Agricultural and Non-agricultural Products
	.... *Baht*		
1981	5,770 (214)	36,200 (1,340)	1:6.3
1982	5,740 (213)	38,400 (1,420)	1:6.7
1983	6,160 (228)	40,600 (1,500)	1:6.6
1984	5,910 (219)	43,300 (1,600)	1:7.3

† Values in parenthesis are U.S. dollar equivalents based on an exchange rate of 27 Thai Baht per U.S. dollar.

Table 3. Per Capita Average Income for Thailand in 1983 by Regions.

Regions of Thailand	Per Capita Average Income	
	Baht	*U.S. $*
North	12,400	461
Central	24,000	889
Northeast	7,150	265
South	16,100	598
East	34,600	1,280
West	25,300	938
Average Income	18,800	695

Many factors account for the low income of people in the Northeast compared with other regions. These include:

Soils

Soils used for cultivation are inherently low in fertility and low in organic matter. They are sandy soils having a low water-holding capacity as well as a low nutrient-retention capacity. Also, many of the soils have undergone some degree of salinization which has caused a serious decline in crop yields and soil productivity.

Water

Agriculture in the Northeast Region is almost exclusively rainfed. While the average rainfall is rather high, drought is common even during the rainy season and can result in crop damage and yield reduction. Facilities and infrastructure for irrigation are lacking. Data from the Agricultural Economics Division, Ministry of Agriculture, show that in 1986 there were only 600,000 ha of irrigated land, or approximately 7 percent of the total agricultural area.

Methods of Growing Crops

The traditional methods of growing crops are still being used in the Northeast. The high level of unemployment during the off-growing season results in the mass migration of people from villages to the cities in search of jobs. Some people also find work in the more developed agricultural areas in the east, west, and south of Thailand. They often find work on sugarcane, cassava, maize, and rubber plantations. Others find jobs in the mining and fishing industries. These people return home when the rice growing season begins, and the migration cycle begins again after the planting and harvesting end.

The Crop Growing Structure

The main economic crops of the Northeast are rice, cassava, maize, sugarcane, and kenaf. Less important crops include cotton, sorghum, mungbean, and groundnut. In the past mixed cropping was encouraged as a means of reducing risk. However, mixed cropping has not been widely adopted by farmers in the Northeast. Farmers have continued to do sole cropping even though it has a higher degree of risk in terms of income. Their main problem involves the market place where prices are generally low because they are unable to bargain effectively to obtain stable market prices.

Farm Livestock Enterprises

Domestic animals that are reared by villagers include buffaloes, cows, pigs, chickens, and ducks. They are an important food source, provide draft power, and are a source of revenue. The methods used for livestock production in the Northeast are rather primitive and breed quality is low. Consequently, the productivity and net returns from livestock are low.

Industry

Large scale industries of the region include sugar mills in Udon Thani, Khon Kaen, Chaiyaphum, and Buriram Provinces and the Phoenix Pulp Mill in Khon Kaen.

Less important industries include jute and rice mills. There are a total of 10 jute mills in Nakon Ratchasima, Khon Kaen, and Udon Thani. Rice mills can be found throughout the region. Based on 1985 statistics, rice mills accounted for approximately 83 percent of the total number of factories in the Northeast.

Cassava mills rank second in number after the rice mills. The cassava industry generally can be found in most provinces in the Northeast. The mills produce cassava flour and pelleted cassava for livestock feed.

Small scale industries such as silk, cotton, and mat weaving have also brought revenue and income to the region.

The Living Environment

Most people in the Northeast have settled in cluster communities such as villages. However, they also live alongside of main roads and in newly established villages. The relationships among the villagers are very strong. They are Buddhists and lead simple lives. This situation, however, is now changing. Their way of life is becoming more like those living in towns. This is partly due to the influence of rural development. The Northeast has the best road system in the country and most villages are connected by roads. This has brought a lot of conveniences to the villagers who can travel throughout the year without difficulty. There is also electricity in most villages, and many people have acquired appliances such as electric fans, electric irons, television sets, and refrigerators.

Conclusions

The population of the Northeast Region of Thailand is one-third of the total population of the country. Its area also comprises one-third of the total country. The climate is tropical savanna with three seasons. Most soils of the region are of low fertility and have salinity problems. Land holdings for agricultural purposes account for about half of the total land area. Per capita average annual income in the Northeast is less than 40 percent of the national average. Such factors as low fertility soils, erratic and insufficient rainfall, lack of water for irrigation, obsolete farming methods, lack of mixed cropping, low quality livestock, and unstable market conditions all contribute to the very low income of Northeast farmers. There are, however, a growing number of important industries such as rice and cassava mills, which provides some employment and will help to improve the economy of the Northeast. The fact remains that agriculture in the region is in need of considerable rehabilitation. Perhaps the highest and most urgent priority is to improve the productivity, fertility, and tilth of agricultural soils. The key to improving soil productivity is through the regular addition of organic amendments such as crop residues, animal manures, green manures, and composts. Improved soil physical conditions and increased soil organic matter content would enhance the retention and storage of water in soils and, in turn, would increase crop yields. Increased soil organic matter would also help to ameliorate such extreme conditions of soil acidity and salinity which are now adversely affecting crop yields in the region. Shifting from sole cropping to mixed cropping would also help to restore soil productivity. Research and demonstration programs should be conducted on farmers' fields for the most effective transfer of technology. The principles of nature farming may be worth serious consideration in this regard.

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Nature Farming and Vegetable Production in Bangladesh

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ABSTRACT. Bangladesh had been practicing a true nature farming in her agriculture until 1960. No agricultural chemicals had been used in crop production prior to that time. Recently, however, many progressive farmers have started to understand the benefit of using fertilizers and insecticides for reaping a good harvest of quality produce. In case of vegetable production, however, use of these chemicals is still in a low profile. Vegetable growers of this subsistence farming community grow vegetables mainly around their homesteads where the land is generally more fertile than the land used for field crops. The general yield level of vegetables in Bangladesh is very poor because of lack of good seed, good varieties, inability and reluctance of the growers to use agrichemicals, and lack of incentives due to improper marketing facilities. Increase of total vegetable production is essential to help solve the nutritional problem and thereby the food problem. Among the many ways and means of increasing vegetable production, improved nature farming technology may have a reasonable role to play.

Introduction

Even though the economy of Bangladesh was never strong during the past couple of centuries, the country used to be self-sufficient in food and the people were generally well-to-do. But since the colonial rulers did not obviously pay attention to the well-being of the people, food production could not keep pace with the ever increasing population. As a result, food shortages and malnutrition have become chronic problems. Rice, the staple food, contributes more than 80 percent of our daily food intake. Although vegetables form an indispensable part of our daily diet, they contribute a very small percentage of total food intake partly due to short supply and health unawareness. If we can grow more vegetables, the problem of existing acute malnutrition and food shortages might be overcome to a significant extent. Under the socioeconomic conditions of Bangladesh, an improved nature farming technology may be worth trying in improving vegetable production.

Nature Farming in Bangladesh

A true nature farming had been in practice in Bangladesh until recently. Prior to the 1970s almost no farmers used any sort of agricultural chemicals. About 30 years ago the government began promoting fertilizer use among farmers for increased crop production by supplying fertilizers to them at a nominal price. Today most farmers are aware of the benefit of using fertilizers. But the use of fertilizers in vegetable production is still minimal. Reasons for this are:

1) Vegetables are grown around homesteads on a small scale, so the growers do not bother to buy fertilizers.
2) The land around homesteads is generally rich in organic matter and more fertile than other agricultural lands.
3) Due to subsistence farming practices, the vegetable growers are satisfied with what produce they get without using agrichemicals.
4) Many people believe that the vegetables grown using fertilizers are less tasty than those produced without fertilizers.
5) Fertilizers are too costly for most farmers.

Today, the use of insecticides on vegetables is negligible, and the use of herbicides has not yet started in the agricultural sector. Sometimes total crops fail due to attack by insect pests. Even under such a situation, an insecticide is not used because of:

1) Ignorance;

2) Unavailability of the required small amount of insecticide;

3) Lack of sprayer;

4) High price;

5) Lack of application knowledge; and

6) Danger of health hazards.

There are, however, a limited number of commercial vegetable growers who use both fertilizers and insecticides to reap a good harvest of quality produce. Due to a lack of knowledge about the safe time-lag between the last insecticide spray and consumption of the vegetables, it is often dangerous to eat the vegetable procured from these commercial growers. Unfortunately, the potential consumers are not generally aware of such a danger.

Vegetable Production

Vegetables occupy a small part of the total cultivated land area of Bangladesh. It is extremely difficult to estimate accurately the total area under vegetables and total production because of scattered small holdings. The area cultivated and total production of vegetables estimated by the Bangladesh Bureau of Statistics is shown in Figure 1. Clearly, the area under vegetable cultivation is small, and has been increasing very slowly. Total vegetable production and the annual rate of increase are also limited. In 1983, a total of 2.71 million Mg of vegetables was produced on an area of 0.31 million ha with an average yield of only 8.7 Mg ha^{-1}. The availability of vegetables per head per day is only 82 g, whereas the nutritionists suggest that, on an average, a person should eat at least 235 g of vegetables a day to maintain good health. This standard is based on the assumption that enough other nutritious food items like meat, milk, egg, fruits, etc. are consumed. These foods are also in scarce supply in Bangladesh. Hence, the standard requirement of vegetables for Bangladeshi people might be much higher than 235 g a day. If the Bangladesh vegetable requirement is calculated based on a conservative estimate of 235 g per day, the present annual vegetable requirement would stand at 10.2 million Mg

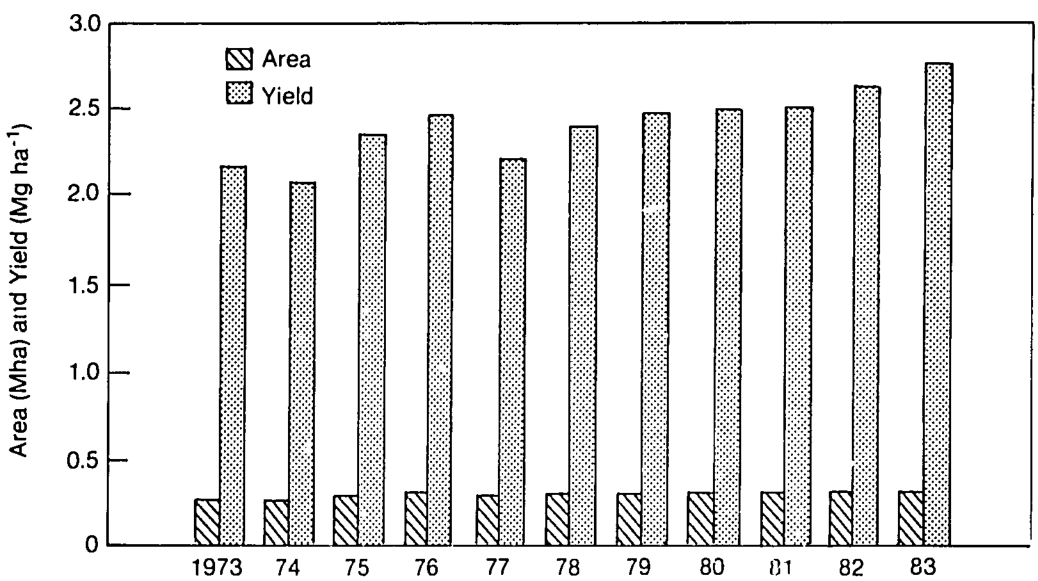

Figure 1. The Area Under Cultivation and Production of Vegetables in Bangladesh from 1973 to 1983.

for the current population of 120 million. In order to raise total vegetable production to 10.2 million Mg, we would need to increase production by 7.5 million Mg, a 300 percent increase.

Food Problems and Vegetables

Currently, Bangladesh has an annual food shortage of 2 million Mg. Since rice is the staple food, we really are talking of a rice shortage. For this reason, the government tries to make up the food shortage by importing rice and by increasing local rice production. This solution requires spending a lot of hard earned foreign currency on imported rice, and doesn't address the acute nutrition problem of the nation. A vast majority of the people suffer from malnutrition. Unless this nutritional problem is addressed as part of the chronic food problem, it is unlikely to be overcome. Since the bulk of the population is poor, they cannot afford to buy enough nutritious foods like meat, milk, etc. As a consequence, malnutritional diseases are common, especially among the peasants. Solving the nutrition problem will result in good health and a more efficient work force. In addition, the food problem will be taken care of automatically and in a much cheaper way. To achieve this, proper emphasis must be placed on the improvement of food items other than rice. Bangladeshi people eat too much rice, to the exclusion of other foods. On an average, each person eats 425 g of rice while he needs only 375 g. If the people can be motivated and their diet modified to consume only the required amount (375 g) of rice, an amount of 50 g rice per head per day would be saved leading to a total saving of 2.2 million Mg of rice per year. This amount is slightly higher than the annual food deficit. The savings will be possible only if rice is replaced in the diet by other food items like vegetables. As mentioned earlier, we need to increase vegetable production by an amount of at least 7.5 million Mg. If this can be done, vegetable consumption will very likely be increased and the serious deficiencies in iron, calcium, protein, and vitamin A will be overcome. In this way, malnutrition might be eliminated. When calculated on a dry weight basis, our food deficit is 1.75 million Mg, of which 1.28 million Mg may be met by the proposed increased vegetable production. This indicates that, at least theoretically, we may overcome the malnutrition problem by producing an additional 7.5 million Mg of vegetables. This increased vegetable supply may make up almost the entire food deficit of the country.

Vegetable Production Constraints

To increase vegetable production by more than 300 percent, doesn't seem to be too difficult. A number of production constraints must be alleviated to achieve this level of production.

Supply of Quality Seeds

Since good quality seed is a prerequisite for good crop production, we must ensure a supply of quality seeds to growers. Seed quality alone may increase crop productivity by 20 to 25 percent. Availability of good seed is the biggest obstacle to increasing vegetable production in Bangladesh. There are no seed companies in this country. Even though the Bangladesh Agricultural Development Corporation supplies some quality seeds to growers, this does not satisfy more than 5 percent of the total requirement. There are many seed merchants in the country who collect seeds from different sources to sell to farmers. But with respect to quality, their seeds are not always reliable. Without other alternatives, many farmers continue to buy seeds from these merchants. A majority of the growers, however, use seeds collected from their own crop, grown from unstandardized varieties of unknown description. Because of using unreliable seeds of improper or unknown description, many problems arise such as:

1) Total crop failure often occurs when early varieties are planted late. For example, buttoning in cauliflower is common when early varieties are planted late in the winter leading to total crop failure.
2) Crops may fail due to seed borne disease.
3) Low yield is obtained when a variety is not genetically uniform in different characters.
4) Low seed vigor at planting leads to poor germination and poor yield.

To help solve seed problems in Bangladesh, the following measures may be taken:

1) A proper seed industry should be developed in either the private or public sector or both, which supplies enough quality seeds to growers in a timely way.

2) The use of certified seeds should be ensured.

3) Proper seed laws should be enacted and strictly applied.

Climatic Problem

Bangladesh has a unique climate for vegetable production. The year is divided into two distinct seasons: rabi (winter from October to March) and kharif (hot, humid season from April to October). The rabi season is suitable for most of the vegetable crops due to relatively low temperature, humidity, and rainfall. Irrigation problems during this dry season hinders production to an extent. Nevertheless, toward the end of the rabi season, a market glut occurs. At peak harvest time, the growers do not even recoup production costs by selling their produce. During the kharif season, however, only a few vegetables can be successfully grown. A few cucurbitous crops, aroids, and vegetable amaranths are the main vegetables at that time. The high temperatures and high rainfall of the kharif season are not conducive for most other vegetables. As a consequence, there is always a serious scarcity of vegetables during the kharif season. In addition, the price of vegetables at that time is very high; so much so that vegetable prices often exceed the price of rice.

To improve vegetable production and supply, we should develop varieties suitable for growing in the adverse weather conditions of the kharif season and drought resistant varieties for the rabi season.

Lack of Appropriate Varieties

Bangladesh imports seeds of many exotic vegetables, almost all of which are hybrids and, therefore, the import of such seeds is a recurrent process. Sometimes crops are raised from imported seeds without suitability studies. Often, crops from such seeds totally or partially fail. Varieties of indigenous vegetables are usually poor in terms of productivity, uniformity, and quality. So we must develop our own varieties of both local and exotic vegetables to assure a timely supply of quality seeds.

Improper Cultural Practices

The successful cultivation of most vegetables requires more care than the cultivation of field crops. But our vegetable growers, many of whom are women, are not aware of modern cultural practices. By following traditional methods of cultivation, they obtain low crop yields. By improving the cultural methods of vegetable production, yields may be increased significantly.

High Production Cost

Cultivation of vegetables is more expensive than the cost of producing field crops, in terms of labor and inputs. For this and other reasons, a commercial vegetable industry is not growing.

Poor Marketing Facilities

Due to the socioeconomic conditions of Bangladesh, vegetables are marketed mainly in the towns and cities. Since the transportation system in the rural areas is poor, marketing of perishable vegetables from the rural areas to urban towns is expensive. As a result, the growers are compelled to sell their produce to middlemen at a very low price. Moreover, during the peak harvest season a market glut causes the poor growers to sell their produce at a throw-away price. Under such a marketing situation, the farmers lose their interest in growing vegetables in excess of their own family needs.

Prospect of Nature Farming with Vegetables

As mentioned earlier, nature farming had been practiced in Bangladeshi agriculture until about three decades ago. Even though many farmers have started using agrichemicals in crop production, almost no vegetable growers use fertilizers and pesticides. For crop nutrition, farmers usually use different organic materials such as cowdung, farmyard manure, and oil cakes. Under such conditions, nature farming technology may help improve vegetable production.

Conclusion

Although the area under vegetable cultivation in Bangladesh is small, the importance of vegetables cannot be overemphasized. Bangladesh is facing a chronic food shortage which is now approaching 2 million Mg per year. For the last few decades, the government has been trying in vain to become self-sufficient in food production. When the planners refer to food they mean rice only, so not much attention is paid to improve the production of crops like vegetables. For the planners, the term food should also include fruits and vegetables which are indispensable in maintaining good health. In fact, existing acute malnutrition problems could be overcome by increasing vegetable production. To meet the minimum daily requirement of vegetables, i.e., 235 g $head^{-1}$ day^{-1}, we should increase vegetable production by about 7.5 million Mg—an increase of 300 percent. If we succeed in attaining this goal, the present food deficit of 2 million Mg might be reduced and the acute malnutrition problem might be solved.

In the subsistence farming community of Bangladesh, vegetables are grown at homesteads on small pieces of land. Consequently, the use of agrichemicals on vegetables is very limited. Most vegetable growers use organic materials instead of fertilizers. The adaptation of nature farming technology to this situation promises to increase vegetable production in Bangladesh.

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Section IV
Regional Experiences II

Organic Farming in Sri Lanka

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ABSTRACT. The agricultural production system in Sri Lanka consists of two traditional and well-defined components. One is the plantation section, established during the colonial period, consisting of large units, and producing perennial crops such as coffee, tea, rubber, and coconut mainly for export. The other is the smallholder sector comprised of small farms which produce most of the country's rice, vegetables, legumes, tubers, spices, and fruits. Fertilizers and pesticides have long been used for the production of plantation crops in Sri Lanka. Until several decades ago, most of the smallholder operations were farmed with little or no input of agricultural chemicals. Today, with emphasis on greater production to meet increased food demands, the use of chemical fertilizers and pesticides is increasing throughout the smallholder sector. There is also growing interest and demand for producing organically-grown food products for export. Some production units have already experienced considerable success in such ventures. Organic food production and marketing could be greatly expanded in Sri Lanka. However, research is needed to develop organic farming systems and practices that are efficient, productive, and profitable.

Introduction

The Democratic Socialist Republic of Sri Lanka, situated off the southeastern coast of the Indian subcontinent, is an island of 65,614 km^2. The geographic location of the country has a major impact on its tropical climate, which is influenced by two monsoons. These monsoons bring abundant rainfall from the northeast and southwest during the months of October to January and April to July, respectively (Domros, 1974).

Due to the availability of rainfall, the presence of a warm, humid tropical climate and rich soil, the country has traditionally been involved in agriculture. Even in the ancient past, Sri Lanka was often referred to as the *Granary of the East.*

The ancient agricultural systems of the country were primarily geared for the production of food for its people, using high levels of technology at that time. These were mainly sited in the north, central, and eastern regions of the island. This region, receives an average annual rainfall of about 1100 mm and only from the northeast monsoon. It has a pronounced dry period during the southwest monsoon, and is designated as the *dry zone.* Today, a complex man-made irrigation system comprises most of the dry zone. At one time this part of the country was self-sufficient in its staple food (rice) production and in most other food commodities, all of which were produced with traditional farming methods and without the use of agricultural chemicals.

During these early times, the central, western, and southern regions of the country produced food crops, but also established perennial cropping systems for production of spice crops. The production of spice crops was confined to this region because of the heavy annual rainfall (2200mm) coming from both monsoons. These agricultural systems in the so-called *wet zone* also produced crops with traditional methods, without using purchased chemical fertilizers. Spice production was responsible for the arrival of traders and, subsequently, the colonial powers from the west.

The productivity of the agricultural sector in the ancient past was primarily based on the use of locally available organic manure and other substances. Ancient literature, preserved in religious institutions, cite the use of organic compounds obtained from leaves, bark, seeds, and roots of trees such as *Azadirachta indica* (neem). Thus, organic farming could be considered as a primary determinant of a once successful agriculture in ancient Sri Lanka.

The Agricultural Situation

After colonization of the country in 1815 by the British, cultivation of coffee, tea, rubber, and coconut emerged as principal agricultural export crops. Consequently, land for food production was lost to these perennial plantation crops. This occurred primarily in the wet zone, because of the availability of suitable land and climate for the perennial crops. Thus, the agricultural sector was divided into two principal components namely, the plantation sector consisting mainly of well-managed, large units of perennial crops, and the peasant food crop sector. The latter generally consists of smallholdings throughout the country, although at one time they were more predominant in the drier regions of Sri Lanka.

The Plantation Sector

The plantation sector established during the colonial period was well-managed for optimal production of export commodities. Since products were exported from the site of production, the nutrients and resources were thus removed from the ecosystem (Cox and Atkins, 1979). These systems became import-dependent and their productivity was based on the application of inorganic fertilizers and other chemicals to maintain soil productivity. A high input of chemicals became a principal requirement of these units, a practice that has been maintained to the present time.

Most of the units producing these perennial plantation crops also use chemical fertilizers to maintain a high level of productivity, which accounts for their success. Hence, the principal agricultural commodities for export and local consumption are generally produced by the use of agricultural chemicals. Currently, because of the demands for increased production of these commodities, increased competition from other countries, and declining commodity prices, the input of agricultural chemicals in the plantation sector is increasing.

The exception to such increased use of agricultural chemicals in this sector is the traditional smallholder spice gardens in the mid-country of Sri Lanka. The intensive cropping of perennial spices in a randomly mixed way has enabled these farmers to establish productive and stable agricultural production systems with minimal input of fertilizers and pesticides. Studies by Jacobs and Alles (1986) and Sangakkara (1989) have described many beneficial characteristics of these ecosystems, including the low input of inorganic chemicals. Thus, in the plantation sector these units can be considered as the principal enterprises that tend toward organic farming. However, with increased demand for spices these units are now beginning to use chemical fertilizers, although pesticide use is generally uncommon.

The Smallholder Sector

The food producing sector of Sri Lanka is characterized by smallholder units, scattered throughout the country. These units produce rice, vegetables, legumes, tubers, spices, and fruits. Due to our increasing population, increased cost of imported food, and diminishing resources for food production, especially land, greater production is the goal of the smallholder sector. The export of produce from these agricultural ecosystems makes them deficient in resources, especially plant nutrients needed to maintain their ecological stability, productivity, and sustainability. Most annual food production units grow two crops per year in seasons determined by the monsoons. These are dependent on chemical fertilizers to replenish plant nutrients that are lost through marketing and export.

The rice producing sector of Sri Lanka is greatly dependent on chemical fertilizers, especially nitrogen and potassium. Most farmers use nitrogen because of proven visible benefits of this nutrient. Increased use of chemical fertilizers and pesticides is also based on the use of improved high yielding varieties that are responsive to these inputs. The government extension programs promote the use of chemical fertilizers to increase yields and to achieve self-sufficiency. Hence, chemical inputs are a vital component of the rice-producing sector of Sri Lanka.

Agricultural chemicals are also an important production input for food crop units in the highlands of Sri Lanka. Again, this is attributed to the demand for greater quantities of food for an expanding population, rather than improved product quality. For example, the vegetable sector of the highlands uses very high inputs of chemical fertilizers and pesticides. Farmers of the drier regions also apply fertilizers, especially nitrogen, to obtain higher yields. This practice has become more and more common due to increased demand for food and the urgency to produce higher yields and to achieve economic viability.

The development of intensive production systems using agricultural chemicals is promoted by extension programs which demonstrate the benefits of chemical usage to farmers. The fertilizer and agrichemical companies also encourage the use of their products through impressive advertising and promotional campaigns that attract farmer participation. They also fund research programs that encourage greater use of their products. Moreover, international funding agencies tend to support research projects that use agrichemicals. Thus, chemical-based agriculture is rapidly becoming commonplace in the food producing sector of Sri Lanka.

Among all food commodities, the fruit and home garden sectors are using very low agricultural chemical inputs. Most fruit farmers do not use pesticides although fertilizer use is increasing. The home gardens which produce vegetables and fruits for domestic consumption are not generally fertilized with chemical fertilizers.

The Organic Farming Sector

Much of the agricultural sector of Sri Lanka has become dependent on agricultural chemicals. Fertilizers, pesticides, and growth regulators are widely used because of the increasing demand for food quantity, rather than quality, from a limited land area. Recently, however, interested individuals have developed organic farming units. These have been established from accumulated knowledge on the benefits of organic farming, and because of increasing demand for export of organically-grown products. These units which are scattered in the wet zone are considered negligible in the agricultural sector, since productivity is somewhat less than the traditional farming units which use agricultural chemicals.

Exports of organically-grown agricultural products to the western world are increasing. Vegetables, fruits, and spices grown without fertilizers and pesticides bring premium prices, thereby enhancing the economic viability of these production units. Nevertheless, the lack of research and extension programs on organic farming is the principal constraint to the development of productive and profitable organic farming in Sri Lanka.

The Future of Organic Farming

It is unlikely that organic agriculture will play a very significant role in meeting the food production requirements of development programs in Sri Lanka. This is because of the ever increasing demand for greater quantities of food, and expressed doubts that strictly organic methods of agriculture can meet this demand.

Nevertheless, the concept of exporting quality foods grown under hygienic conditions without the use of agrichemicals, especially pesticides, and at premium prices, has attracted attention. Some production units have already been established with considerable success, and there appears to be an opportunity for their expansion to meet export demand. These units could also be developed under the self-employment schemes pursued by the state to solve unemployment problems. Export production villages could easily be established to cater to the demand for organically-grown products. Thus, the future of organic farming is promising in Sri Lanka primarily as an export or specialized commodity enterprise, rather than a general agricultural program.

A major constraint to the expansion of organic agriculture is the lack of research on the viability and sustainability of organic farming under local conditions. Research on organic farming has been centered around the use of some by-products such as straw (Amarasiri and Weerasinghe, 1977) as substitutes for imported inorganic fertilizers for rice and other highland crops. A few isolated studies have reported the use of *Azadirachta indica* (neem) as a pesticide.

Thus far, little research as been done on the development of process technology for producing organic manures and devising strategies for their rational use in Sri Lanka. This is primarily due to the emphasis placed on increased production by traditional means and the unavailability of funds for organic agriculture. Some microbiological studies on organic matter decomposition are currently in progress.

The primary use of organic farming methods is seen in home gardening and some smallholder farming operations. However, with sufficient emphasis on research at the initial stages, followed by a well-developed extension program, government awareness can be directed toward organic agriculture. This can become a productive and profitable venture for Sri Lanka, especially as a specialized export-oriented enterprise that will generate much needed foreign exchange for the country.

Summary and Conclusions

The agricultural sector of Sri Lanka is the primary source of livelihood of its people. This sector is dependent on the monsoonal rains which provide the primary determinant of successful agriculture. Thus, based on annual rainfall, the country is divided into three principal agroclimatic zones, i.e., the wet, intermediate, and dry zones.

The agricultural enterprises of Sri Lanka have traditionally been divided into two principal components, a perennial plantation crop sector and a peasant smallholder food-producing sector. Moreover, the traditional perennial spice crop units are found as smallholdings in the mid-country wet zone. The peasant sector can be categorized into lowland rice and highland food, vegetable, and cash crop production units. This sector is well-established and in the ancient past produced most of the food requirement using low levels of technology.

Because of our increasing population and expanding industrial development, the demand for agricultural commodities in recent years has greatly exceeded production. Thus, intensive agricultural production units were developed with the use of modern technology, especially the use of fertilizers and other agricultural chemicals. This trend is common to all systems because of the demand for greater quantity, rather than improved quality, of agricultural products.

The status of organic farming in Sri Lanka can be considered as marginal, due to the heavy demand for increased production of agricultural commodities. While organic fertilizers and associated products played a major role in rural agriculture in the past, these are not widely used at present. The exception to this is the mid-country spice gardens, where there is little or no use of chemical fertilizers and pesticides. The natural recycling of organic litter and crop residues maintains their soil productivity. In addition, a few smallholder allotments may not use agrichemicals primarily due to lack of funds for purchase of such inputs.

Recently, there has been an increasing demand for organically-grown agricultural commodities in the developed world. This has led to the establishment of selected units generally by interested individuals and nongovernmental organizations. These units produce export commodities for specific markets. Several principal buyers in the western world have provided incentives for establishment of organic farming enterprises. The scope of organic farming in Sri Lanka could readily be expanded to meet the demand for export-oriented products. This could help to resolve unemployment problems that afflict the country, and to generate much needed foreign exchange. Research is needed to develop productive, profitable, and sustainable organic farming systems.

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Utilization of Organic Wastes and Natural Systems in Malaysian Agriculture

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ABSTRACT. Malaysia produces about 35 and 59 percent of the world's supply of rubber and palm oil, respectively. It is also the third largest producer of cocoa, (200,000 Mg of raw cocoa beans annually) and the fourth largest producer of pepper (14,200 Mg annually). Other crops produced are rice, pineapple, vegetables, and tropical fruits. To maintain its competitiveness in the world market, there are efforts to reduce the production costs of these crops. The goal is to develop highly efficient management practices without sacrificing environmental quality and the living standard of agricultural workers. Production costs can be reduced by using agricultural waste products for fertilizers and practicing biological pest control, while increasing crop productivity and soil fertility. During the past decade, research was directed toward the use of agricultural wastes and natural systems for crop production. The agricultural wastes include palm oil mill effluent (POME), rubber mill effluent (RME), empty oil palm fruit bunch (EFB), and animal wastes. The natural systems include barn owl, rhizobium, Elaeidobius kamerunicus beetles, and honey bee. Currently, the plantation sector is extensively utilizing POME, RME, and EFB as substitutes for chemical fertilizers, Elaeidobius kamerunicus for pollinating oil palm fruit bunches, barn owl for rodent control, and rhizobium for nitrogen fixation by legume crops. The vegetable and fruit farmers are using animal and agricultural waste products as sources of plant nutrients and as soil conditioners. They are using honey bees to improve pollination of coconut and fruit crops.

Introduction

Malaysia, with an area of 329,293 km^2, leads the world in rubber production with about 1.5 million Mg annually. This supplies about 35 percent of the world's rubber requirement. Malaysia is also the world's largest producer of palm oil, supplying about 59 percent of the world's needs or 4,530,000 Mg of palm oil per year; the third largest producer of cocoa, with an annual production of about 200,000 Mg of cocoa beans; and the fourth largest producer of pepper with an annual production of 14,200 Mg of white and black pepper. In addition to these, Malaysia also produces rice, vegetables, fruits, pineapple, and a variety of other crops.

With a population of about 16 million people, Malaysia can ill afford to mismanage its agricultural resources. It must be very efficient to sustain production and competitiveness in the world market, without sacrificing the living standard of its people and environmental quality. Towards this end, Malaysian agriculture has been relatively successful. Currently, Malaysian farmers and workers are earning higher incomes than ever before and environmental pollution is being contained. Part of this success is due to the utilization of agricultural wastes as fertilizers and soil conditioners, and the use of natural systems, which have made our agriculture more profitable, efficient, and sustainable.

Palm Oil Mill Effluent (POME)

The production of 4.53 million Mg of crude palm oil generates about 13.5 million Mg of effluent. This is a potential source of pollution since raw POME has an average biochemical oxygen demand (BOD) of 35 g l^{-1}, or 100 times that of sewage (Mohd Tayeb et al., 1987). The chemical composition of POME (Table 1) indicates that it can be used as a source of fertilizer. Indeed, experiments conducted during the last 20 years have shown that proper utilization of POME can improve crop yields, reduce production costs, and can be used without causing environmental pollution. Application of POME can be done either through furrow, flat-bed, sprinkler, or tractor/tanker systems. Application rates must be carefully controlled because an excessive application can decrease crop yields and increase environmental pollution, especially in the waterways. Examples of POME utilization and its expected benefits are shown in Table 2.

Table 1. Nutrient Content of Palm Oil Mill Effluent Zin et al., 1988).

Type	BOD	N	P	K	Mg
	mg l^{-1}				
Raw Effluent	25000	948	154	1960	345
Digested (Anaerobic)					
Stirred tank	1300	900	120	1800	300
Supernatant	450	450	70	1200	280
Bottom slurry	2000	3550	1180	2390	1510
Digested (Aerobic)					
Supernatant	100	52	12	2300	539
Bottom slurry	225	1500	461	2380	1000

Table 2. Effect of Palm Oil Mill Effluent on Oil Palm Yield (Wood and Lim, 1989).

Soil Type	Effluent Type	Application System	Application Rate	Application Frequency	Yield Increase
			cm	*round y^{-1}*	%
Loamy	Supernatant	Flatbed	10.0	6	20
Loamy	Tank	Flatbed	6.7	4	23
Loamy	Raw	Flatbed	3.3	4	8
Clayey	Tank	Sprinkler	2.5	6	18
Loamy	Supernatant	Sprinkler	18.0	6	19
Loamy	Raw	Tractor/tanker	4.6	12	12
L C L†	Supernatant	Furrow	38.0	12	39

† L C L: loamy clay (lateritic)

Table 3. Nutrient Content of Empty Fruit Bunch from Oil Palm (Chan et al., 1980).

Nutrient	Concentration	Amount
	%	*kg ha⁻¹*
Nitrogen	0.35	5.4
Phosphorous	0.03	0.4
Potassium	2.29	35.3
Calcium	0.18	2.7
Magnesium	0.15	2.3

Empty Fruit Bunch (EFB)

Empty fruit bunch of oil palm (EFB) comprises about 22 percent of fresh fruit bunch, and it is estimated that 5 Mg of EFB are produced per hectare per year (Chan et al., 1980). With a total of 1.6 Mha now planted to oil palm, about 8.0 million Mg of EFB are produced every year. Since EFB is relatively rich in nutrients (Table 3), it is currently used as a source of fertilizer.

Empty fruit bunch can be applied directly to the field or applied as bunch ash, which is especially good for acid sulphate soils. However, because of air pollution caused by burning of EFB, the current practice is direct application of EFB to the field. Methods of application vary from spreading between rows, around the palms, or piled at the center of four palms. Which ever method is selected, the pile thickness should not be more than 50 cm to reduce the probability of providing a breeding ground for rhinocerous beetles. The best way is to spread it out rather than piling (Loong et al., 1987).

Application of EFB has been shown to increase yields of oil palm grown on acidic soils. Application of 15 Mg of EFB ha^{-1} y^{-1} can increase yields up to 23 percent (Hong and Halim, 1980). Rates of application vary from 12.5 Mg ha^{-1} y^{-1} to 150 Mg ha^{-1} y^{-1} (Khoo and Chew, 1978; Singh et al., 1981). Zin and Tarmizi (1983) recommended the use of 30 to 50 Mg ha^{-1} y^{-1} for immature palms and 50 to 100 Mg ha^{-1} y^{-1} for mature palms. Loong et al. (1987) recommended the use of 37 Mg ha^{-1} y^{-1} of EFB supplemented with urea and CIRP, while Singh et al. (1989) obtained an increase of up to 23 percent with EFB applied at a rate of 75 Mg ha^{-1} y^{-1} together with 0.75 kg of urea and 1.0 kg of rock phosphate. Recent results showed that it is best to apply EFB at the time of field planting. This can shorten the immaturity period by several months and can increase yield as much as 75 percent (Lim and Chan, 1989).

The use of EFB also improved the nutrient content of the soil, increased the soil pH and cation exchange capacity, reduced erosion, decreased nitrogen losses, and controlled weed growth (Singh et al., 1981; Loong et al., 1987). Utilization of EFB in oil palm production enabled the plantations to save from \$31 to \$173 ha^{-1} y^{-1} compared with the use of chemical fertilizers.

Rubber Factory Effluent (RFE)

Producing and processing 1.5 million Mg of rubber produces 9 million Mg of effluents which consist mainly of block rubber, sheet rubber, crepe rubber, and concentrated latex effluents (Yeow, 1983). The BOD generated by these effluents is estimated to be about 200 Mg d^{-1} which is equivalent to the BOD generated by 4.6 million people. If not treated and utilized, it can become a major pollutant in Malaysian waterways. Since RFE contains reasonable amounts of plant nutrients (Table 4), it can be used as a fertilizer substitute.

The estimated fertilizer equivalent from the total annual production of RFE is 45.3, 11.4, 41.2, and 35.6 thousand Mg of ammonium sulphate, rock phosphate, muriate of potash, and kieserite, respectively (Yeow, 1983).

RFE has been shown to be beneficial in the production of oil palm and some annual crops. Proper application of RFE can increase oil palm yield by up to 20 percent, and rubber by 5 to 10 percent. Recommended application rates are 2.0 to 2.5 kg N equivalent per palm per year for oil palm, and 100 kg N per hectare per year for rubber (W[illegible] and Lim, 1989).

Biological Nitrogen Fixation

In Malaysian agriculture, particularly in rubber and oil palm production, the planting of leguminous cover crops inoculated with rhizobium bacteria, between rows and on slopes, is done to fix atmospheric nitrogen and to control soil erosion. The increased utilization of rhizobium is evidenced by the ever increasing sales of rhizobium inoculum. For example, the sales made by the Rubber Research Institute of Malaysia (RRIM) increased from 1170 kg in 1984 to 1500 kg in 1988. The sales for 1989 through September surpassed 1580 kg (Noordin, 1989). *Centrosema pubescens* has been reported to fix 238 kg N ha^{-1} y^{-1} (Watson, 1961). Tan et al. (1976) reported that growing a mixture of *Calapogonium caeruleum* and *Pueraria phaseloides* can greatly reduce or eliminate the application of fertilizer nitrogen in rubber for up to 15 years. Currently, leguminous cover crops inoculated with rhizobium are extensively used in the new planting and replanting of rubber, oil palm, and fruit orchards. Rhizobium bacteria is also widely used to inoculate the seeds of other legume crops such as groundnut and soybean.

Animal Wastes as Fertilizers

Animal wastes are used extensively by vegetable and orchard farmers. Among these are chicken dung, cow dung, prawn dust, pig dung, and goat/sheep dung. The nutrient composition of these materials is shown in Table 5.

In one survey it was found that 10 percent of the vegetable farmers used only organic fertilizers. Some 48 percent used both organic and inorganic fertilizers, 51.5 percent used chicken dung, 20.4 percent used cow dung, 4.7 percent used prawn dust, and 6.7 percent used pig dung (Sundram and Shamsuddin, 1983).

Pollination of Oil Palm

Elaeidobius kamerunicus was introduced in Malaysia in 1981 to enhance the pollination of oil palm. Since its introduction, the weevil has helped oil palm growers to increase yields and reduce their production costs by eliminating the need for assisted pollination (Chan et al., 1987). Among the changes caused by this weevil are increased fresh fruit bunch yield; increased bunch weight; decreased number of bunches produced; and improved bunch components. The average bunch weight was increased from 14.1 to 28.6 kg (Chan et al., 1987); bunch number was reduced from 135 ha^{-1} to 110 ha^{-1}; the fresh fruit bunch yield was increased by about 12 percent; and the kernel to bunch extraction was increased from 4.4 to 6.2 percent (Chan et al., 1989).

Syed and Salleh (1987) reported that 1500 adult *E. kamerunicus* weevils can pollinate a female inflorescence to an acceptable minimum level of pollination, or about 50 percent fruit set. To obtain an optimum level of fruit set, about 70 percent, nearly 3000 adult weevils per female inflorescence are required. This requires extra precaution to ensure that the number of predators (i.e., rats) are kept to a minimum. Unfavorable climatic conditions can also reduce the weevil population.

Barn Owl for Rodent Control

The increase in oil palm hectarage from 3200 ha in 1925 to 1.6 Mha in 1987, has correspondingly increased the rat population which feeds on the oil palm fruits. Rats can be controlled to some extent by using either poison bait or biological control measures. Currently, some oil palm plantations in Peninsular Malaysia are using barn owls (*Tyto alba*) to combat the rat problem. Studies conducted on oil palm estates showed that the diet of the barn owl is almost exclusively rats. An adult owl consumes at least two rats

Table 4. Nutrient Content of Rubber Factory Effluent
(Yeow, 1983).

Element	Mixed Concentrate/ Cuplump	Block Rubber
	mg kg^{-1}	*mg kg*$^{-1}$
Nitrogen	718	182
Phosphorus	43	81
Potassium	461	246
Magnesium	28	51
Calcium	133	10
Zinc	0.63	0.42
Copper	0.20	0.22

Table 5. Nutrient Content of Some Animal Waste Materials
(Sundram and Shamsuddin, 1983).

Waste	N	P	K
	....	%	....
Chicken dung	3.99	2.10	1.52
Cattle dung	2.00	0.65	2.00
Pig dung	1.90	1.30	0.30
Goat dung	2.00	0.87	2.17
Prawn dust	2.17	1.36	0.27

per day (Duckett, 1986). A method has been developed to increase the barn owl population, whereby nest boxes are built on tall poles which attract pairs of young birds. In due course, they produce young which also need nest boxes. When properly constructed, positioned, and maintained, the nest boxes proved to be an effective and economic investment for rodent control (Duckett and Karuppiah, 1989). Since rats are also a major pest in rice fields, research is underway to determine if the barn owl can be used effectively as a control measure. Thus far, results have been encouraging.

Honey Bee for Pollination of Coconut and Fruit Crops

The use of the honey bee (*Apis cerana*) in Malaysian agriculture started in a serious way in 1981 with the formation of the Malaysian Bee Keeping Research and Development Team, spearheaded by University of Agriculture, Malaysia. This team obtained grants from the International Development Research Centre (IDRC), Canada, from 1983 to 1986 and from 1987 to 1990. Currently, IDRC has also provided a grant for promotion of bee keeping from 1989 until 1991. About 1000 bee keepers are registered in the Malaysian Bee Keepers Association formed in 1988. Historically, the honey bee has been the natural pollinator of coconuts and, with the current intensification of bee keeping, coconut yields have increased from 30 to 50 percent. With the current increase in star fruit production, honey bees are also being used in this industry. An increase of up to 100 percent in star fruit production has been obtained due to honey bee assisted pollination (Makhdhir, 1989). A serious problem facing honey bee assisted pollination is the indiscriminate use of pesticides which can drastically reduce honey bee populations.

The future of the honey bee in Malaysian agriculture is very promising considering that the Malaysian government is expanding the fruit orchard industry which forms the basis of honey bee assisted pollination. Research is also being conducted on carpenter bees (*Xylocopa latipes*) for the pollination of passion fruit.

Conclusion

The use of agricultural waste products and natural systems have helped Malaysian agriculture in improving crop yields, production efficiency, and profitability while, at the same time, reducing the risk of major pollutants generated by the processing of agricultural crops like rubber and oil palm. The ability to use these products safely and profitably can be attributed to the research carried out by government agencies and the private sector. This research has focused on solving problems which beset the agricultural industry, and which if not solved would lead to environmental pollution of major proportions.

Research is also being conducted to determine the feasibility and practicability of using biological methods for controlling weed and pest infestations, and the use of microorganisms to improve nutrient use efficiency by crops grown on highly weathered soils.

Little actual natural farming is yet practiced in Malaysia. Although some experiments on natural farming systems have been conducted, research results so far are not encouraging. Among the various constraints and problems that limit natural farming in Malaysia are:

1) Weed infestations;
2) Insect pests;
3) Plant diseases and pathogens;
4) Infertile and unproductive soils; and
5) Weather conditions which promote weed, pest, and disease infestations.

Nevertheless, a few individuals are still trying to produce food through natural farming methods. Perhaps with the help of innovative research carried out by scientists who are dedicated to the principles of natural farming, proper and effective methods and techniques can be developed so that natural farming will one day become a reality in Malaysia.

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Nature Farming in the Philippines

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ABSTRACT. For almost three decades, farmers in the Philippines have been using chemical fertilizers, pesticides and growth regulators in their crop production strategies. Despite the high cost of these inputs, and the farmers' awareness that they can adversely affect soil fertility, food quality, human and animal health, and environmental quality, they are used extensively because there are few alternatives that would be considered practical and feasible. One reason for this is that university-based research has strongly promoted the use of agricultural chemicals as the best means of achieving the highest possible crop yields. The predominant question then is how can the farmers shift from a chemical-intensive agriculture to one that is based on the utilization of natural systems, and still maintain their economic viability. It is encouraging that there are some efforts now underway by university researchers, the Philippine government, and the private sector to develop nature farming as an alternative to chemical-based agriculture.

The government, in cooperation with nongovernment agencies, needs to set forth certain policy initiatives that would promote the necessary research for the development of productive, profitable, and sustainable natural farming systems, and to ensure that such knowledge is transferred effectively to the farmers.

Introduction

For the last 20 to 30 years, farmers in the Philippines have been practicing a chemical-based agricultural production strategy. The detrimental effects from the use of agricultural chemicals (fertilizer, pesticides, growth regulators, growth hormones, and antibiotics) on the farmer, the farm, the wealth of the nation, the environment, and future generations have been well documented and discussed (Aspiras, 1987; Medina and Ridao, 1987; Onate, 1989; Loevinsohn et al., 1983).

The crucial issue or problem that requires firm resolve is "how do we shift from chemical-based agriculture to one which is sustainable and nature-based?"

In cases where the soil is very acidic and the soil fertility is low, the pest population is extremely complex. Under these conditions, there is a resurgence of new pests, evolution of new biotypes and physiologic races. A sudden shift or withdrawal in the use of fertilizers and pesticides may cause drastic yield reductions. Field trials show that yields may be reduced by as much as 50 to 60 percent (FSSRI Annual Report, 1987). Such yield reductions are obviously unacceptable to farmers, to society, and to the nation as a whole. Yield reductions may mean massive food shortages and incalcuable or unimaginable consequences.

These apprehensions or issues raised against a nature farming approach may not be real in practice. The fear of yield decline could be avoided. This paper presents the results of a university-based research initiative on nature farming, and a case study of a farmer-initiated nature farming system, including a discussion of its implications and some policy imperatives.

University-Based Research on Nature Farming

University-based research is still mostly classified as mainstream research and characterized as being high yield-oriented. This necessitates the use of high yielding varieties, nourished adequately with chemical fertilizers, and protected with an array of pesticides. The capital scarcity of farmers, the risks involved in farming, and the increasing level of environmental pollution are posing serious questions on whether the current mainstream research can be sustained. Certainly the objective of supplying the necessary food and fiber required by our population can be achieved. But at what cost?

In view of these developments, efforts are now underway to evaluate nature farming as an alternative. Mainly, the research being conducted is focused on the input side of production. This research is directed toward minimizing or reducing the input costs of production. This is referred to as Minimum Input Farming (MIF).

The objectives of the research are twofold: to determine how best to minimize the use of chemical fertilizers and pesticides.

The following research is directed toward minimizing the use of chemical fertilizers:

1) Use of rice straw, corn stover, and sugarcane trash as mulch and fertilizer;
2) Green manuring with azolla and sesbania for lowlands, and mungbean for the uplands;
3) Use of poultry, hog, and cattle/carabao manure;
4) *Rhizobium* inoculation of legumes (soybean, mungbean, peanut);
5) *Azospirillum* inoculation of crops belonging to the grass family (sugarcane, corn, sorghum, napier);
6) Crop rotation schemes involving legumes as the rotational crop; and
7) Intercropping and cover-cropping between nonlegume and legume crops, e.g.,
   a) sugarcane + mungbean, soybean, or peanut;
   b) corn + mungbean, soybean, or peanut;
   c) coconut + winged bean or kudzu.

Addressing the objective of minimizing the use of pesticides, the following research is being undertaken:

1) Use of botanical pesticides. Specific research being conducted includes: the identification and inventory of plants that have pesticidal properties; the identification of mode of action (repellant effect, toxicity); and the extraction procedure, preparation and method of application.
2) Application of the concept/practices of integrated pest management (IPM). Specific research includes: establishing critical threshold for various pests in different crops; and monitoring farmers acceptance of IPM.
3) Use of biological control agents or natural enemies. This area of pest management has not been thoroughly studied in the Philippines. Only *Bacillus thuringensis* and *Trichograma*, which are known worldwide, have been investigated; other species remain to be found.

These university-based research efforts have similar characteristics. They are conducted by individual researchers representing their own discipline, bias, or training. In addition, they are conducted on a project-to-project basis, as their duration is coterminous with the project duration.

There are negative implications for the research. There is no integration into actual farming systems. Rarely are farmers involved in the research process. They are short-term, and data obtained are generally indicative measures. There is no long-term monitoring of effects.

Case Study of a Farmer-Initiated Nature Farming System

Starting in 1980, Mr. Lorenzo Joset† began to shift his farming practices from chemical-based to purely natural farming methods. Neighboring farmers, including his family, thought then that Ka Toti (as he is fondly called) was crazy. Nobody believed that he could shift a conventional, chemical-based farming system to a system of nonchemical, natural/organic farming. First, the soil was unproductive and infertile due to 15 years of intensive rice production. Second, there was a heavy infestation of weeds and other plant pests that had been devastating to crop growth and yield. Also, it was thought that if he did not spray, all the pests in the area would migrate to his farm since all of his neighbors applied pesticides regularly. It was hypothesized that this would accentuate the pest infestations to even more devastating proportions.

Amidst pressures and fears, Ka Toti still pursued the idea of changing his farming method. During the first year of transition, his crop yield was reduced from 80 to 120 cavans ha^{-1} with chemical inputs, to as low as 30 cavans ha^{-1} without chemical fertilizers and pesticides‡. For a man who relies solely on farming for his livelihood (although his wife is a government employee) and supports his children in college, this yield decline was most discouraging. This drastic yield decline sparked considerable doubt and misunderstanding in his family. However, as time progressed, crop yields gradually increased. Five years later, he was getting 2.3 Mg ha^{-1} to 5 Mg ha^{-1} of rice in his best yielding paddy. At present (1989), he obtains an average yield of 3.5 Mg ha^{-1} and he is getting as high as 6.0 Mg ha^{-1} of rice in his best yielding paddy.

What are the features of Mr. Jose's farm? Ka Toti's farm is essentially a landscape mosaic or a diversified farm. The 6.0 ha farm is subdivided into the following parcels:

1) A 3.0 ha pasture area where he maintains 5 cows, 1 bull, and 6 calves for a total of 12 head of cattle. These ruminants forage in the pasture area and they are not fed with any concentrate or salt. They are just provided with drinking water. The pasture area is planted with acacia trees that provide protection for the animals during the hot summer.

2) About 0.5 ha is planted to ipil-ipil *(Leucaena leucocephala)*. The ipil-ipil trees are cut every two years for fuelwood. The fuelwood is sold, which provides cash for purchasing fuel to run the irrigation pump for the rice paddy. Regrowth of ipil-ipil occurs rapidly.

3) About 0.8 ha is planted to fruit trees dominated by mangoes. This area, includes the home lot and a small pond for fish and ducks.

4) The remaining area of 1.8 ha is devoted to intensive rice production and is monocropped throughout the year. This area is subdivided into 52 paddy lots for weekly planting. Each lot is planted to rice at least three times a year.

Such diversity provides the basis of stability and productivity in Mr. Jose's farm. He has structured his farming system for maximum complementarity and integration of enterprises on a whole farm basis. The 3.0 ha pasture area serves as the biofertilizer factory for his intensive rice paddy production. The cattle dung is collected and spread in the rice paddy. To facilitate dung collection, the cattle are tethered at a certain place during the night. Hence, the biomass (grasses and legumes) that the cattle consume is converted into valuable meat for the family's needs and into organic fertilizer for the rice paddy. The wooded area (about 1.3 ha) which is planted to ipil-ipil and fruit trees (mango is the dominant fruit tree) serves as a buffer zone. Weeds in this area are allowed to grow profusely including the viny weeds that tend to cover the mango canopies. This area serves as a wildlife or bird sanctuary, a habitat for beneficial insects, and additional pasture space. The fruit trees provide food for the family and supplemental income during a good fruiting year.

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† Mr. Lorenzo Jose's farm is at Solib, Floridablanca, Pampanga, Philippines. It is at the Central Plain of Luzon Island, 120 km north of Manila.

‡ 1 cavan = 50 kg

The remaining 1.8 ha devoted to intensive rice cultivation derives benefits from the noncultivated area. The 3.0 ha pasture provides manure that replenishes the nutrients removed through rice production. The other potential benefits depend on a favorable microclimate for the 1.8 ha rice paddy.

The diversity and integration of the farm's enterprises may not fully explain the success of Ka Toti in his rice culture. His rice cultural practices are fined tuned to nature farming from seeding to harvesting. A description follows.

Seedling Preparation

Enough seeds to plant a given paddy of about 300 to 400 m^2 are germinated in a plate. The seedlings are transplanted 8 to 10 days after seeding.

Spacing and Row Orientation

Seedlings are transplanted into rows 40 cm apart, with 5 cm between hills and at one seedling per hill. Rows are oriented east to west for maximum light penetration into the canopies.

Weed and Irrigation Management

The paddy is saturated with water after transplanting. Sometime later, the paddy is drained so that the seedling will be sturdier and more resistant to pests. Still later, the paddy is again flooded. This alternate wetting and drying, from a chemical-based rice farming viewpoint, is not recommended because it can accelerate the volatilization loss of applied N fertilizer.

Harvesting, Spreading and Incorporating Straw

At harvest, rice stalks are cut close to the ground. Immediately, the harvested palay are threshed using a manually pedalled thresher. Rice straw is then spread evenly in the same paddy where rice was harvested. The paddy is then irrigated to moisten the straw. Two weeks later, plowing is done with a carabao. Depending on the soil conditions and fertility, *Sesbania* seeds are sown by broadcasting. One week later, the same paddy is harrowed and prepared for planting.

The cultural practices cited here are interrelated and provide a basis of explanation for his success in following a nonchemical nature farming approach. Other practices also contribute to Mr. Jose's success.

First, the early transplanting of seedlings on a seed-to-hill basis facilitates the unhampered root development—a requirement in growing a healthy plant to better resist pest infestation.

Second, the judicious use of water effectively controls the weeds but not enough to weaken the plant with too much submergence. The practice of maintaining just enough moisture in the paddy field allows spontaneous biological nitrogen fixation (SBNF) through living organisms. This is enhanced by the availability of organic carbon from the rice straw incorporated after every harvest, and the cattle dung applied (Patriquin et al., 1986).

Third, the large row spacing allows maximum light penetration even up to harvest time. The availability of light allows SBNF in paddy fields which reportedly can fix as much as 30 to 40 kg N ha^{-1} (Rice and Soil, IRRI).

Therefore, the development of healthy, sturdy, and well-rooted rice plants is the result of early transplanted seedlings, judicious use of water, and a planting pattern that allows light to penetrate below the plant canopy. Additional benefits derive from these practices. Rice plants can resist more insect infestation because they are healthy and growing vigorously. Also, there is no imbalance in available plant nutrients and, thus, no nutritional stress in the seedlings. Such stress factors impacting the plant would tend to attract insects and diseases. Another benefit is a unique microclimate, resulting from the large row spacing and increased light transmission, that is not conducive to pest population buildup.

Finally, with time, the nonuse of pesticides has paid off. The population ratio between beneficial to harmful insects, which is now 60:40, has shifted toward the beneficial ones (Gapud, 1989 unpublished report).

Discussion and Implications of Nature Farming Systems in the Philippines

Transforming the practices of farmers, who are dependent on the use of synthetic chemical fertilizers and pesticides is not a simple, physical transformation. Farmers' awareness of the high cost of fertilizers and pesticides, the degradation of their soils, and the decline in their quality of life, has not provided sufficient motivation to shift from chemical-based farming to natural/organic farming practices.

Mr. Lorenzo Jose is not a typical Philippine farmer. How many are there like Mr. Lorenzo Jose? We do not know exactly, but they are still few in numbers.

The shift from chemical agriculture to nature farming systems requires a change in the farmer's attitude and philosophy of life. It requires changes in his life style, consumption pattern, and value orientation. But it will take more than this. The vision that "farming is liberation" should be a guiding principle. He who controls the farm inputs controls the farming operation and, thus, controls the resources and enjoys the material gains. This is called value orientation. What do farmers value more? Freedom or food? Freedom may include one's ability to produce adequate food.

Would this require violent or radical change? There is no correlation between the liberation movement launched by peasants and natural farming. The socialist north similarly pursued chemical agriculture as the basis of their food production strategy in the same way as did the capitalist north (Khor Kok Peng, 1989). The cultural revolution in China is an exception, because China to begin with had long practiced nutrient cycling from organic materials (FAO, 1977). When they declared a closed door policy, there was a need to develop a more efficient nutrient cycling process (crop-animal-human-fish-crop). Hence, the pronouncement "turn waste into useful products" was a necessary survival strategy (King and Cleveland, 1980). Furthermore, during that time, the Chinese did not have the technology to manufacture fertilizers and pesticides. At present, however, they are using large quantities of chemical fertilizers and pesticides, especially for their export crops.

What about university-based research? At present, the university-based research establishment has been slow to respond to the needs of farmers who would want to change from chemical-intensive farming to organic/natural farming. The reasons are obvious:

1) The training of researchers is still primarily chemical-oriented. Research on nature farming is still believed to be backward or traditional. Their training and doubts about natural farming as a viable alternative to chemical agriculture inhibit them from pursuing a scope of research on natural farming systems, other than the piecemeal and cost-reducing technologies cited earlier.

2) Funding for university-based research generally favors research with high impact and with easily measurable results in the short-term. Nature farming research provides positive effects over the long-term rather than in the short-term.

However, there are now initiatives by some researchers and faculty members to pursue nature farming research. Small grants are being obtained from private donors. In the Philippines, there are presently several nongovernment organizations (NGO's) that are working at the grassroots level. The realities of farming in the uplands where they normally operate, that is, the resource-scarcity of the farmers and the remoteness of these locations, are major constraints to intensive crop production. Most of these NGO's emphasize natural farming systems and the use of traditional methods for their assistance projects.

What about government-supported food production programs? It is logical for any government to have a centerpiece program directed toward achieving food self-sufficiency or an adequate supply of food and other basic staples for the people. In a Third World setting, food is a political issue since it can often determine whether a government succeeds or fails (Perlas, 1989). This makes conservation goals in nature farming politically unwise. Program planning and implementation emphasize immediate impact as the overriding criteria. Activities that yield results in the long term get less priority (Mendoza, 1989). Chemicals (fertilizer and pesticides) and genetically uniform high-yielding cultivars provide immediate increases in production. Incentives and support services are designed and packaged for extension and delivery to the farmers. As an incentive to farmers who will join the government in this massive food production program, soft loans, crop insurance, marketing, and technical assistance are generously provided (Department of Agriculture, 1989).

In the Philippines, however, there is some positive attention for nature farming practices, although nature farming is not part of the government's food production strategy. The Office of the Undersecretary for Special Concerns emphasizes natural farming practices for their projects in tribal and upland farming communities.

Some Policy Imperatives for Nature Farming

1) Research efforts must be directed toward the appropriate approaches and strategies in various agroecosystems. There are existing technologies and considerable information about nature farming; however, there is a need for fine tuning in accordance with the unique and varied conditions of a given farm. A definite budget for nature farming research and development must be allocated. Similarly, extension services must be strengthened and redirected in support of nature farming systems.

2) A percentage of the tax gain from the sale of fertilizers and pesticides should be allocated for research and development of nature farming systems and practices to ensure a more sustainable agriculture, and to facilitate the transitional process from chemical-based agriculture to natural farming.

3) A media campaign is essential. Agrichemical promotion schemes should emphasize that "pesticides are poison." They are hazardous to health and they can pollute and degrade the environment.

4) A public awareness campaign regarding the potential adverse effects of fertilizers and pesticides, in addition to their yield-enhancing qualities, should be undertaken. Similarly, the benefits of organic waste recycling should be given equal time and space in all types of media.

5) Nature farming requires institutional efforts that will help reorient the thinking and values of the population. First, this should start in the family, the basic unit of society, by instilling practices on proper waste disposal (i.e., wastes should be separated into degradable and nondegradable fractions to facilitate recycling programs).

6) Family enterprises such as backyard gardening should be emphasized and supported with extension-type bulletins. Educational institutions at all levels should incorporate topics and courses on organic waste recycling, home gardening, integrated production systems, biomass agriculture, and nature farming.

7) A law or executive order is urgently needed to ban the practice of burning crop residues. At present, rice farmers are burning their rice straw to facilitate land preparation, and to destroy insects, weeds and diseases. A rice field yielding 80 cavans ha^{-1} usually yields 4 Mg of straw. The equivalent nitrogen fertilizer lost from burning straw at this yield level is equivalent to four bags of urea (Mendoza, 1989).

8) A comprehensive law on nutrient cycling (farm, household, municipal, and industrial/factory wastes) and waste disposal must be enacted. Such energy and nutrient resources should be properly recycled to sustain our present and future generations.

9) An all-embracing land use policy, with the objective of assuring the future population of adequate land, forest, and water resources, must be formulated and implemented. The rapid conversion of prime agricultural lands to urban development and industrial sites is highly visible right now.

10) Nature farming is generally based on the principle of biological diversity. This biological principle can be translated into tangible benefits by mandating that each barangay, town, province, and region of the country establish woodlands and plant trees for fuel, construction materials, and food.

11) The Philippines ranks 13th among the most highly populated countries. With a population growth rate of 2.4 percent, it is impossible for basic services to keep pace. Because of intense population pressure and inadequate employment opportunities, cultivation of marginal upland areas with slopes of more than 18 percent has become a widespread practice. This has resulted in extensive degradation of the land resource base by erosion. Hence, a comprehensive family planning program is urgently needed.

12) The debt issue is exacting a heavy toll on resources utilization. With 40 percent of our national budget allocated to debt service, projects and programs that would relieve poverty are sacrificed. Unfortunately, there is a direct relationship between poverty and pollution. Easier terms on loan repayment, including the possibility of a debt moratorium, must be given serious consideration.

13) Finally, government executives, legislators, and policymakers should recognize sustainable agriculture as an economic, social, political, and environmental necessity. The shift to natural farming systems and practices will be significantly catalyzed with strong government support and will move us toward our ultimate goal of a more sustainable agriculture.

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Nature Farming in Pakistan

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ABSTRACT. Small farmers in Pakistan face significant constraints to agricultural production. Productivity has suffered declines due to salinization of soils, loss of soil fertility, and erosion. Farmers without the economic means to buy costly inputs may be able to increase their productivity through low-input, nature farming techniques. Studies have been conducted to determine the efficacy of green manures, farmyard manure, and composts as substitutes for chemical fertilizers. Alternative nutrient sources for fish and animal feeds, and biological control agents are also being investigated. A number of low-cost strategies designed to increase the productivity of small farmers through nature farming are discussed.

Introduction

Pakistan lies between latitudes 24° to 37° N, and longitudes 61° to 76° E. To its north and northeast are situated the world's loftiest mountain ranges: the Hindukush, the Karkorams, and the Himalayas. For the most part, its western border with Afghanistan and Iran is also rugged mountainous country. Its northern and western sections are crossed by a number of passes. All these physical features have a great bearing not only on the temperature and rainfall pattern of Pakistan, but also on the general circulation of the atmosphere over southern Asia.

Diversity and conspicuousness of landscape are the two outstanding physiographic features of Pakistan. Prolonged organic disturbances, changing climate, unique hydrologic features, and human activity have played significant roles in sculpturing the landmass of Pakistan. Geographically, Pakistan has a highly diversified landscape and environment. Snowclad mountains, vast sandy deserts, extensive river systems, and piedmont plains have combined to give rise to a wide range of agricultural soils. Pakistan's soils can be divided by ecological regions: the northern mountainous region, western mountainous region, potwar upland, sandy deserts, piedmont plains, old river terraces, sub-recent river plains, recent river plains, and the Indus Delta (Figure 1).

Agricultural Resources and Production

Soil

The total geographical area of Pakistan is 79.6 M ha, whereas the cultivated area is only 20.7 M ha which is about 20 percent of the total area (Table 1). There is another 9.51 M ha which is categorized as culturable wasteland. Out of the total cultivated area, about 4.70 M ha remain fallow. This leaves a net sown area of 16.0 M ha of which 4.81 M ha are cropped more than once, thus raising the total cropped area to 20.8 M ha. The rainfed area constitutes about 20 percent of the cultivated land.

Soil Constraints

Salinity/Sodicity. The salt-affected soils in the Indus Plain occur in specific physiographic positions and were formed as a result of a gradual redistribution of salts in the landscape. This process has extended over several thousand years but has been hastened by the rise in the underground water table following the establishment of extensive irrigation systems and the emergence of barriers to natural drainage from railway and road networks. Thus, the rising water table served to intensify an already existing condition. The extent of salt-affected land is shown in Table 2.

Soil Fertility Problems. The soils of Pakistan are generally calcareous, with high pH and low organic matter content (less than 1 percent), and are known for their high phosphorus fixing capacity. Thousands of fertilizer experiments conducted at research stations, farms, and in the farmers' fields since 1950 have confirmed widespread deficiencies of nitrogen and phosphorus. Still there are some areas, particularly sandy soils and tubewell commands, where crop response to potassium is common. Deficiencies of zinc and iron have been identified in rice and fruit crops.

Soil Erosion. Soil erosion is another important aspect adversely affecting the productivity of our cultivated soils. Water and winds are imperceptibly eroding the upper fertile parts of the cultivated soils. The process of erosion is more active on sloping lands. Estimates by the Punjab Agricultural Economic Information Board indicate that about 1.4 M ha are affected by erosion in the Punjab alone which accounts for 17.7 percent of the total area of 11 affected districts. In the North West Frontier Provinces (NWFP) about 9,400 ha are severely eroded.

Irrigation Water

The development, use, and distribution of the physical resources, namely water and land, have played a major role in the process of agricultural development in Pakistan. Pakistan's agriculture is mostly irrigated. Our surface irrigation system is dependent upon the Indus River and its two tributaries, i.e., the Jehlum and Chenab. The system consists of three storage reservoirs, namely Tarbela, Mangla, and Chashama; 16 barrages, 12 inter-river

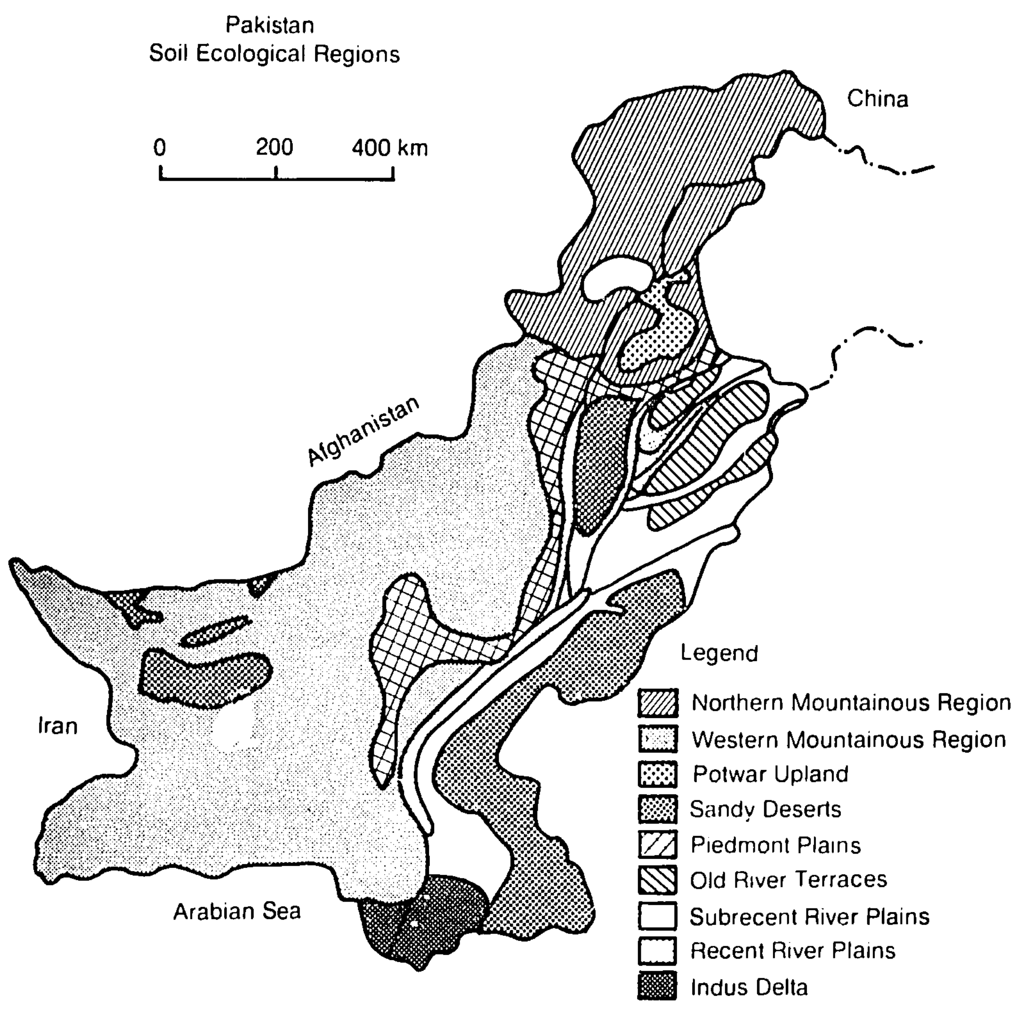

Figure 1. The Soil Ecological Regions of Pakistan.

link canals, two syphons, and 43 main canals. The total length of the canal system is about 50,315 km, with 88,600 outlets. The length of the farm channels and water courses is 1.6 million km. Water flows by gravity from northeast to southwest. Although this is one of the most magnificent irrigation systems in the world, it has problems of transit losses of water from seepage and evaporation which amount to a 40 percent loss from canal headworks to the farmgate. The farmgate availability of canal water is 70 million acre feet (MAF) compared with 98 MAF at the canal head. Another source of irrigation water is ground water which is mostly saline or saline-sodic, but about 40 MAF of good quality water was pumped for irrigation during 1986-87 from 250,000 tubewells.

Table 1. Land Utilization in Pakistan During 1986-87.
(Agricultural Statistics of Pakistan 1987-1988).

Geographical Area	Forest	Culturable Wasteland	Cultivated Land	Current Fallow	Rainfed Area
.... *M ha*					
79.6	3.06	9.51	20.7	4.70	4.13
Net Area Sown	**Total Cropped Area**	**Salt-Affected Area**	**Waterlogged (1975)**	**GCA†**	**CCA‡**
.... *M ha*					
16.0	20.8	5.8	7.0	17.0	14.0

† Canal Command Area
‡ Culturable Canal Command Area

Table 2. Extent of Salt-Affected Land in Pakistan.

	NWFP†	Punjab	Sind	Total Indus Plain
.... *10^3 ha*				
Total CCA‡	320	7890	5350	13,600
Within CCA: Salt-affected area	14	1610	1530	3160
Outside CCA: Salt-affected area	502	1130	1020	2650
Total salt-affected area	516	2740	2550	5810

† NWFP: North West Frontier Provinces.
‡ CCCA: Culturable Canal Command Area

Crop Production

Agriculture was the dominant sector of the economy after independence in 1947, contributing about 53 percent of the Gross Domestic Product (GDP). Its share of the GDP has inevitably fallen as other economic sectors such as manufacturing, construction, and services, which were rudimentary at the time of independence, were developed on a priority basis. Nevertheless, agriculture continues to remain the single largest sector of the economy. It contributes 26 percent of the GDP and provides employment to over half the country's labor force. Agriculture and agro-based products account for 80 percent of the country's total export earnings and this sector supplies many of the major industries with raw materials. In turn, agriculture consumes 33 percent of the industrial finished goods. Almost 70 percent of the country's population continues to reside in the rural areas.

The climate of Pakistan is suitable for growing a number of crops such as wheat, rice, millet, corn, sorghum, and barley as food grains (Table 3); sugarcane, cotton, tobacco, jute, and sugarbeet as cash crops; gram, mungbean, mash bean, lentil, peas, and some others as pulses; and rapeseed, mustard, sesamum, groundnut, soybean, sunflower and safflower as edible oilseeds (Table 4). Apart from this a number of fruits including citrus, mango, banana, apple, guava, apricot, peach, pears, plums, grapes, pomegranate, dates, and almonds, and a wide variety of vegetables are also grown (Table 4). Distribution of the cropped area, as recorded in 1986-87, was 56, 16, 7, 2, 2, and 1 percent for food grains, cash crops, pulses, oil seeds, fruits, and vegetables, respectively, with an additional 16 percent for other crops.

Livestock Production

The livestock sector contributes some 31 percent of the agricultural value added. The present role of the livestock sector in the economy of Pakistan reflects the historic role and importance of livestock and their products in the rural economy. The primary purpose of livestock-keeping has been, and largely still is, to supply basic dietary needs to the farm family as well as draft power, with the generation of cash income as a secondary

Table 3. Food Grain Production in Pakistan in 1987-88
(Agricultural Statistics of Pakistan 1987-88).

Crop	Area	Production	Yield
	10^3 ha	*10^3 Mg*	*kg ha^{-1}*
Wheat	7310	12,700	1730
Rice	1960	3240	1650
Corn	854	1130	1320
Millet	293	135	462
Sorghum	320	181	565
Barley	145	112	771
Total Food Grain†	10,900	17,500	–

† Totals may not be precise due to rounding.

Table 4. Production of Cash Crops, Pulses, Edible Oils, Fruits and Vegetables in Pakistan in 1986-87 (Agricultural Statistics of Pakistan 1987-88).

Crop	Area	Production
	10^3 ha	*10^3 Mg*
Cash crops	3470	42,200
Pulses	1220	557
Edible oils	4000	307
Fruits	427	3590
Vegetables	249	3080

objective. The close integration of the livestock sector with the rural subsistence economy is made possible by strong reliance of livestock on the cultivated regions for crop residues and fodder crops. Rangelands provide the other major source of animal feed. On this basis it has been possible to meet the minimum dietary requirements for animal protein and fats that supplement the cereal staples which have traditionally dominated the diet. The present availability of feed and fodder consists roughly of one-third from crop residues, one-third from grazing, and the remainder from other crop by-products, all expressed in terms of the total digestible nutrients (TDN). Livestock populations in 1976 and 1986 along with inputs and outputs in 1986 appear in Table 5.

At present, the milking animals consume about 38 percent of all the available feed and fodder. Full feeding would require that 55 percent of all feed and fodder would be consumed by dairy animals, furthermore reducing the already meager diet of the other animals. In any case, it is clear that the most efficient way to increase milk production is by providing larger quantities of feed and fodder to the present stock of milking animals. The main problem is limited feed resources and increasing animal numbers. There are about 0.42 million Mg of fish produced in the country. The consumption of fish products is very low in Pakistan, about 1.1 kg per capita annually. This is due partly to the somewhat insular dietary habits of Pakistan and partly to the high price of fish.

Forestry

Together with watersheds and rangelands, forests are a vital component of the ecosystem of the country. As a discipline, forestry is closely interconnected with soil resources, water management, wildlife conservation, and livestock. As little as 5.2 percent of Pakistan's total area (including Azad Kashmir) is forested. However, only about 30 percent of this total is economically utilized while the balance is basically under protective management. Out of the total forest area of 4.85 M ha, 3.30 M ha are state owned and the remaining 1.55 M ha, though mainly managed by forest departments, are privately owned.

The annual per capita domestic energy requirement is equivalent to 0.4 m^3 of fuelwood. For a population of 98.4 million in 1984-85, the fuelwood requirement was 39.4 million m^3. Approximately 53 percent of these requirements are being met from such sources as kerosene oil, natural gas, coal, cow dung, and agricultural residues, while the rest are met from fuelwood. Fuelwood consumption in 1984-85 was estimated at 19.7 million m^3.

Table 5. Livestock Populations in Pakistan and Production Inputs and Outputs for 1986.

Livestock	Number		Animal Units	Feed Intake		Output	
	1976	1986†		TDN‡	DP§	Meat	Milk
	10^6		*10^6*	*10^3 Mg*		*10^3 Mg*	
Cattle	14.8	17.6	16.1	18.4	1.56	340	2830
Buffalo	10.6	15.8	15.9	20.0	1.77	270	8640
Goats	21.7	30.3	2.87	3.33	0.27	230	743
Sheep	18.9	23.5	2.34	2.92	0.23	165	30
Poultry	32.0	137	1.20	2.71	0.39	135	(8630)¶
Others#	3.66	4.60	4.60	4.37	0.33		
Total††			43.0	51.7	4.55	1140	12,200

† TDN: Total digestible nutrients.
‡ DP: Digestible protein.
§ Camels, horses, mules, etc.
¶ Production of eggs (Million).
# All other values reported here are for 1986.
†† Totals may not be precise due to rounding.

Farm Business in Pakistan

Farming in Pakistan is done in a physically demanding environment. This is the case for both irrigated as well as rainfed agriculture. The rural population, labor, and unemployment figures appear in Table 6. The most serious inequities at present exist in the rural areas mainly because of Pakistan's inherited land ownership pattern. About 38 percent of the total cultivated area is operated by 73 percent of the farmers with an average holding of 5 ha or less (Table 7). The remaining 62 percent of the cultivated area is operated by only about 27 percent of the farmers with average size farms of 5 ha or more. The basic inequity among landholders is clearly reflected in the differences in their respective economic and social positions. The larger landowners have ready access to water, credit, fertilizers, and other resources. By comparison a sizable proportion of the small farmers do not have comparable access to credit (Table 8) and are unable to manage inputs efficiently. This results in higher production costs per unit area or per unit of output. The small farmers reap relatively poor yields and receive lower prices in the marketplace for their output than the large farmers. A major part of the products such as milk, meat, vegetables, maize, pulses, and millets are raised by small farmers. However, there are neither officially fixed prices nor any procurement programs for these commodities. As a result, market margins may go as high as 50 to 60 percent as compared with 10 to 15 percent for commodities for which officially fixed prices and procurement programs have been arranged.

Table 6. Population, Labor and Employment Status in Rural and Urban Areas of Pakistan in 1987-88 (Agricultural Statistics of Pakistan 1987-88).

	Total Number	Rural	Urban
		10^6	
Population	84.2	60.4	23.8
Labor force	30.5	18.9	11.6
Small livestock holders (landless)	1.5		
Landless	.5		
Population growth rate, %	3.1		

Table 7. Number and Area of Private Farms Classified by Size (1980).

Farm Size	Farm Number	%	Farm Area	%	Cultivated Area	%
ha	10^6		*M ha*		*M ha*	
Under 0.5	0.33	8	0.10	N†	0.09	N
0.5 to under 1	0.37	9	0.28	1	0.25	2
1 to under 2	0.69	17	0.97	5	0.89	6
2 to under 3	0.68	17	1.63	9	1.51	9
3 to under 5	0.92	23	3.57	19	3.28	21
5 to under 10	0.71	17	4.70	25	4.12	26
10 to under 20	0.26	6	3.39	18	2.78	17
20 to under 60	0.10	3	2.80	15	2.03	13
60 to above	0.01	N	1.62	8	0.92	6
All farms‡	4.07	100	19.1	100	15.9	100

†N Negligible.

‡ Totals may not be precise due to rounding.

Table 8. Availability of Institutional Credit by Farm Size in the Punjab (Census of Agriculture, 1980).

Farm Size	Total Credit	Loan Size	Index†
	%	*Rs farm*$^{-1}$	
Small	3.9	66	100
Medium	35.4	320	485
Large	60.7	3260	4930

† Small farms = 100.

Constraints of Small Farmers

A small farmer's ability to raise his productivity and income level is constrained by the following factors:

1) **Agronomic-Technological Constraints.** These constraints have to do with the quality of land, including location and soil fertility, amount of water available, cropping practices, incidence of diseases and pests, and limited availability of agricultural technologies adapted to small farm conditions.

2) **Economic Constraints.** These have to do with the conditions of markets (prices they receive and pay) and incentives (subsidies and taxes). The small farmer does not have the financial means to make the necessary inputs at the proper times. He is forced to sell a large portion of his output at harvest time and often at low prices to settle his outstanding accounts.

3) **Structural-Institutional Constraints.** These include small holdings and their fragmentation, insecurity of tenure, access to extension services, credit, storage facilities, transportation, infrastructure, and unfavorable public policies.

4) **Socio-Political Constraints.** Small farmers have no organization and no power to influence governmental policies in their favor. Large farmers and large landlords have major claims to economic and social power and, hence, leadership. Unfortunately, the agriculture-oriented institutions are not structured or organized to accommodate the interests of small farmers. Even those few schemes designed to benefit the small farmers neglect to involve them in either the planning or implementation phases and the program usually fails.

Under the above mentioned unfavorable farming infrastructure, a revolution in agricultural production is only possible if low external input technologies for crop and livestock production are developed with the small farmer as the principal recipient, although large farmers would also benefit. The proposed strategy demands an interdisciplinary approach by the scientists of various agricultural fields.

The principal theme behind the strategy is the concept of nature farming which is a system of practicing maximum agricultural production, making the best possible use of the natural agroecosystem and environment. In this system the fertility is restored by using farmyard manures (FYM), composts, green manures, industrial wastes, and other plant nutrient sources. Plant diseases are controlled through the genetic diversity of the cropping system, spraying of extracts of indigenous plants, allelopathy, and other natural controls. This system encourages farmers to make the best use of all crops and livestock products and their natural interdependence. It also encourages us to explore fully the agricultural potential of an environment with minimum use of external and costly inputs. Although many farmers claim to have practiced some of the techniques used in nature farming, few if any have followed a holistic approach to nature farming.

Nature Farming

Some of the work done in Pakistan on aspects of nature farming is as follows:

Replacement of Chemical Fertilizers with Biofertilizers

Green manures when integrated with chemical fertilizers can increase N use efficiency and the yields of rice and wheat (Tables 9, 10). A number of green manures like *Sesbania aculeata* (cannabina), *Sesbania rostrata*, *Crotalaria juncea* (sunnhemp). *Cyamopsis tetragonoloba* (guar), *Leptochloa fusca* (Kallar grass), *Cajanus cajan* (pigeon pea), and *Pennisetum typhoides* (pearl millet) are being evaluated as substitutes for chemical fertilizers. It has been found that 60 to 70 kg N ha^{-1} can be replaced by green manuring of *S. aculeata* and *S. rostrata*.

Farmyard manure (FYM) and composts are good substitutes for chemical fertilizers. There is a tremendous potential for producing greater amounts of FYM The statistics indicate that the annual production of N, P_2O_5 and K_2O from animal manures is 1.75, 0.688, and 1.80 million Mg, respectively. These figures are actually greater than the annual chemical fertilizer consumption of these same nutrients which is estimated at 1.33, 0.409, and 1.78 million Mg, respectively (Table 11). In experiments where FYM was applied in lieu of chemical fertilizers, it was found that 5 Mg ha^{-1} of FYM can replace 60 kg N, 40 kg P_2O_5 and 30 kg K_2O (Table 12).

Table 9. Grain Yield of Rice and Wheat as Affected by Green Manure Replacement of Chemical Fertilizers (Nabi, 1985; Zaka, 1986).

Treatment	Paddy Yield†		Wheat Yield‡	
	1985	1986	1985-86	1986-87
	Mg ha^{-1}		*Mg ha^{-1}*	
Check	3.96 c§	3.40 c	3.58 d	3.27 c
PU¶	5.29 b	4.50 b	5.22 c	3.96 b
S. aculeata+PU	5.19 b	5.23 ab	5.91 c	4.56 a
S. rostrata+PU	5.56 a	5.60 ab	4.37 bc	4.40 a
FYM + PU	5.14 b	4.78 b	4.74 ab	4.37 a
Sunnhemp + PU	-	5.88 a	-	4.20 ab
Guara + PU	-	5.53 ab	-	5.50 a

Rice = KS-282, Wheat = Pak-81, Soil (Typic Camborthids)

† 87 kg N ha^{-1}.
‡ 116 kg N ha^{-1}.
§ Column values followed by the same letter are not significantly different at the 5% probability level.
¶ PU, prilled urea.

Table 10. Grain Yield of Rice as Affected by Green Manure/FYM Replacement of Chemical Fertilizers (Sadoki Farm-NARC, 1988).

Treatment	N Rate	Grain Yield
	kg ha⁻¹	*Mg ha⁻¹*
Check	–	3.92
AS†	90	6.68
AS + *S. aculeata*	90	7.88
AS + Straw (10 Mg ha^{-1})	90	7.21
AS + FYM (10 Mg ha^{-1})	90	7.71
PU‡	90	6.33
PU + *S. aculeata*	90	7.38
PU + Straw (10 Mg ha^{-1})	90	6.75
PU + FYM (10 Mg ha^{-1})	90	7.08

† AS, ammonium sulfate.
‡ PU, prilled urea.

Table 11. Increase in Fertilizer Consumption, Production, and Importation in Pakistan Since 1970-71. (Pakistan Economic Survey 1987-88)

Year	Consumption					Production	Importation
	N	P_2O_5	K_2O	Total	Increase		
	10³ Mg				%	*10³ Mg*	
1970-71	252	30.5	1.2	283	—	133	151
1975-76	445	102	2.8	551	94.4	327	182
1980-81	843	227	9.6	1080	96.0	640	574
1985-86	1130	350	33.2	1510	40.0	1130	331
1986-87	1330	400	42.6	1780	18.0	1210	522

Table 12. Replacement of Chemical Fertilizers by FYM for Rice and Wheat in a Ustalfic Haplargid (Zaki, 1989).

Treatment $N-P_2O_5-K_2O$	Rice Yield Cv. Bas-370	Wheat Yield Cv. Pak-91
kg ha^{-1}	.... *Mg ha^{-1}*	....
0-0-0	1.64 e†	3.20 f
120-0-0	1.94 e	3.58 e
120-80-0	3.36 bc	4.57 b
120-0-60	3.00 d	3.68 d
0-80-60	3.01 cd	3.78 c
120-80-60	3.50 b	4.72 a
120-80-60 + FYM (10 Mg ha^{-1})	4.15 a	4.83 a
60-40-30 + FYM (5 Mg ha^{-1})	4.41 a	4.57 a
FYM (10 Mg ha^{-1})	4.42 b	4.08 bc

† Column values followed by the same letter are not significantly different at the 5% probability level.

Replacement of Chemical Amendments by Physical and Biological Treatments

Studies were conducted on the reclamation of coarse-textured, saline-sodic soil with rice cropping. The yield of rice was significantly higher where subsoiling was done compared with the application of gypsum.

Replacement of Maize Grain with Manure-Molasses Silage

This was done for feeding broiler chicks with regard to weight gain, feed consumption, feed efficiency, and cost of production. The rations containing 12.5 percent dried cattle manure-molasses silage in place of maize grain, on a protein basis, resulted in higher weight gain and net returns (Table 13). Further increase in the percentage of manure caused a reduction in live weight.

Replacement of Commercial Fish Feed with Poultry Droppings

Results have shown that 43.2, 41.4, and 1.9 percent higher fish yields were obtained when broiler manure, layer manure, and cow manure were used in place of commercial fish feed (Table 14).

Table 13. Replacement of Maize Grain with Manure-Molasses Silage for Broiler Chicks (Ali, 1987).

Ration	Avg. Wt. Grain/Bird	Avg. Feed Consumed/ Bird	Avg. Feed/ Bird Wt.	Cost of Feed	Cost of Prod.
	g	*g*	*g g*$^{-1}$	*Rs kg*$^{-1}$	*Rs*
Maize grain	1470	3240	2.21	3.47	7.68
Manure silage, 12.5%	1530	3700	2.41	3.23	7.80
Manure silage, 25%	1460	3700	2.53	2.90	7.37

Table 14. Fish Yields Obtained from Replacement of Commerical Fish Feed with Poultry Manure and Cow Manure (Javaid, 1989).

Treatments	Broiler Manure	Layer Manure	Cow Manure	Commercial Fish Feed	Control
% N	4.60	3.84	1.48	4.80	–
% P	1.62	1.84	1.08	2.85	–
% K	1.32	1.20	1.27	0.98	–
Fish yield, kg ha^{-1} yr^{-1}	5060 a†	4880 b	2930 c	2870 d	767

† Row values followed by the same letter are not significantly different at the 5% probability level.

Studies on Plant Derived Pesticides

Extracts of indigenous plants such as neem *(Azadirachta indica)* are being evaluated as biological control agents. They are using different mixtures of different crop species or varieties which could buffer against disease losses by delaying the onset of the disease, reducing spore dissemination, or modifying conditions such as humidity, light, temperature, and air movement. They are also interested in some of the associated plants which can function as repellents, antifeedants, growth disrupters, or toxicants in an effort to avoid using poisonous chemicals which can kill beneficial insects, natural predators, and soil microorganisms.

Other Strategies to Strengthen Natural Farming in Pakistan

Agriculture in developing countries has to function under a wide range of conditions and, consequently, must use a number of different strategies. Diversity is very important for the farm unit to ensure the best possible use of internal and external factors like climate, soil conditions, markets, communications, capital, labor, and time.

The following measures can certainly help the economic revival of the small farmer as well as help to sustain agricultural productivity through nature farming:

1) Development of local agricultural technologies suitable for small farms based on local natural resources, climate, landscape, soil, water, indigenous vegetation, and animals and human resources such as labour, experience, and skills. The use of external inputs such as commercial fertilizers and pesticides should be minimized as far as possible for economic reasons in order to satisfy criteria of ecological sustainability, and to enhance the health and independence of the farmers. Indigenous knowledge of the agroecological system, traditional methods of agriculture, and local forms of farmers' organizations are the starting points from which new technologies based on scientific insights and experiences in comparable situations can be developed.
2) Adoption of high value and short duration crops like vegetables, fruits, and edible oils.
3) Adoption of agroforestry so as to integrate trees into cultivated fields or farming systems to improve soil fertility and microclimate, to prevent soil erosion and produce fuelwood, timber, fodder, or edible products.
4) Adoption of integrated pest management in which pests are countered by a mixture of preventive, mechanical, biological, and chemical means.
5) Adoption of integrated nutrient management in which soil is kept healthy and its fertility is enhanced by means of organic fertilization through a number of natural processes such as buffering, nutritive capability of organic materials, nitrogen fixation by means of bacteria, and recycling plant nutrients from below the rooting zone by means of deep-rooting crops.
6) Adoption of multiple cropping systems in which optimum use is made of light, space, and nutrients.
7) Recycling of nutrients by returning crop residues and the organic wastes from food processing back to the field.
8) Integration and coupling of livestock-fish-poultry operations and crop production systems to maximize the utilization of wastes and by-products from one component as production inputs for another.
9) Adoption of water and nutrient harvesting in rainfed areas with the use of special structures to capture runoff and nutrients.
10) Microclimate management by using mulches and shelterbelts to influence temperature, airflows, and humidity.
11) Adoption of water and soil conservation by countering erosion through influencing runoff and airflow.
12) Adoption of an agroecosystem oriented policy for marketing, extension, and education.
13) Selection and breeding of agricultural crops and livestock based on productivity and site-specific conditions.

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Livestock Manure Recycling in Korea by Anaerobic Digestion

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ABSTRACT. The pollution problems of rural areas in Korea have increased in recent years mainly because of increased farm animal populations and inadequate management of manure. Farmers need to manage animal manures properly to minimize the potential for environmental pollution.

One option involves the principle of anaerobic digestion, whereby animal manures are converted into high energy fuel (biogas) and into fertilizer and feed. The process also reduces the number of parasite eggs and pathogens, and helps to abate offensive odors in the slurry.

Introduction

Korea's economic development plan has resulted in the rapid growth of industrialization and urbanization which, in turn, has brought new pollution problems.

Pollution from livestock manure was largely ignored until the early 1980s. However, population growth and the increased demand for meat and dairy products greatly expanded dairy and livestock production, which created serious pollution problems from improper handling of animal manures.

One cost-effective method of disposing of animal manure is by anaerobic digestion. The technology is relatively simple and produces a valuable fuel (biogas), a useful liquid fertilizer and an animal feed, and at the same time minimizes the pollution potential of a waste material.

This paper will discuss the anaerobic digestion technology and its benefits to livestock farms of Korea.

Livestock Manure Production

The major contributors to environmental pollution in Korea in recent years are cattle and swine. As shown in Table 1, the number of cattle and swine in Korea has increased rapidly, from 3.3 million in 1981 to 6.9 million head in 1988. Accordingly, as the number of livestock increased, the amount of manure increased, with a production of almost 11 million Mg in 1988. This corresponded to a progressive increase in the biochemical oxygen demand (BOD) of the manure.

Today, the huge volume of manure produced by livestock farms has created a serious pollution problem which must be dealt with.

The high content of suspended solids, the high levels of nitrogen and phosphorus, the increased biological chemical oxygen demand, and chemical oxygen demand (COD), has resulted in the pollution of farmland, ground water, and the environment.

Principles of Anaerobic Digestion

Today, the production of organic waste materials from animal production and processing is unavoidable because of increased human population and consumer demand for dairy and meat products. Many of these wastes, however, can be converted into usable forms through anaerobic digestion. In this technology the organic materials can be decomposed anaerobically by microorganisms over a range of temperature and moisture conditions.

Studies of the microorganisms that are capable of this type of fermentation have been conducted for many years. However, there are two types of microorganisms that play a major role in anaerobic digestion. These are the facultative anaerobic bacteria that convert cellulose to glucose during the initial decomposition of the substrate, and obligate anaerobic bacteria, i.e., strict anaerobes, that are responsible for the final step in

Table 1. Number of Cattle and Swine in Korea and Manure Production from 1981 to 1988.

Year	Number		Collectable Manure		BOD
	Cattle	Swine	Cattle	Swine	
	10^6		10^4 Mg y^{-1}		10^4 Mg y^{-1}
1981	1.5	1.8	493	158	48
1982	1.7	2.2	558	193	56
1983	2.2	3.6	723	315	78
1984	2.7	3.0	887	263	85
1985	2.9	2.9	953	254	89
1986	2.8	3.3	920	289	90
1987	2.4	4.3	788	377	86
1988	2.0	4.9	657	429	83

transforming the fermentation products into biogas and useful slurry fertilizer. The biogas generally consists to 30 to 40 percent carbon dioxide (CO_2) and 60 to 70 percent methane (CH_4).

Flexible Dome-Type Anaerobic Digester

The plant consists of a rectangular concrete digester and a flexible tarpaulin cover. The cover is installed over the digester by attaching the edges of the cover with a concrete channel surrounding the digester. The concrete channel is filled with water to provide a seal for preventing gas leakage (Figure 1).

During cold weather, the digester is heated by the circulation of hot water from a biogas-fired boiler. A polyethylene plastic sheet is installed over the digester to minimize heat loss.

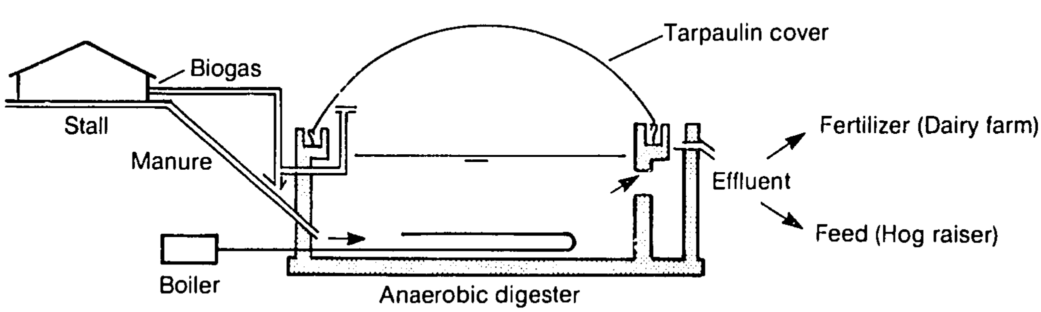

Figure 1. Schematic Diagram of Flexible Dome Type Digester.

The optimum scale of the plant for 40 head of cattle, or 80 head of swine, is 20 m^3. The installation cost for this plant is about $2,300 U.S.

Anaerobically Digested Slurry as a Fertilizer

The effluent slurry from the anaerobic digestion process has long been recognized as a valuable biofertilizer, because it can supply essential nutrients to crops and improve the physical and chemical properties of soils, making them more productive for crops. The percent composition of a rather typical slurry from anaerobic digestion of animal wastes is shown in Table 2. In addition to providing essential plant nutrients, the slurry is largely comprised of water which can also be utilized by crops.

A field experiment, in which slurry was applied at a rate of 12 Mg ha^{-1} for two years, showed that the content of soil organic matter was increased by 0.5 percent, bulk density declined by 10 percent, and total porosity increased by 4 percent (Table 3). There was also a substantial increase in soil phosphorus from the slurry.

The application of slurry to corn, sudangrass, and soybean gave yield increases of 29, 31, and 56 percent, respectively, compared with plots which received only chemical fertilizer (Table 4).

Anaerobically Digested Sludge as a Feed

Studies were conducted to determine the change in chemical composition of swine manure after anaerobic digestion, and whether the sludge from this process would be suitable as a feed supplement for swine. The sludge mixed feed (SMF) was formulated by mixing anaerobic fermentation sludge (AFS) and commercial assorted feed (CAF) in the ratio of one to four.

Table 2. Percent Composition of Slurry from Anaerobic Digestion.

Moisture	Total Solids	Volatile Solids	Total Nitrogen	P_2O_5	K_2O	CaO	MgO
			%				
98.3	1.7	1.0	0.11	0.15	0.19	0.16	0.06

Table 3. Change in Soil Chemical and Physical Properties from Slurry Application.†

Treatment	Soil Depth	Bulk Density	Porosity	P_2O_5	OM
	cm	*g cm⁻³*	%	*ppm*	%
Control	0- 5	1.19	55.2	71	1.4
	10-20	1.30	50.9	32	1.4
Slurry‡	0- 5	1.08	59.2	100	1.9
	10-20	1.24	53.3	40	2.0

† Soil: Clayey, Typic Haplucalf

‡ Slurry: Applied at a rate of 12 Mg ha^{-1}.

Table 4. Effect of Fermented Slurry and Chemical Fertilizer on CropYields.

Treatment	Corn	Sudangrass	Soybean
	.... $kg\ ha^{-1}$		
Chemical fertilizer	10,500	4,800	158
Fermented slurry	13,500	6,300	246

Table 5. Content of B-Complex Vitamins Found in Swine Manure, Commercial Assorted Feed (CAF), Sludge Mixed Feed (SMF), and Anaerobic Fermentation Sludge (AFS).

Materials	Thiamine (B_1)	Riboflavin (B_2)	Pyridoxine (B_6)	Cyanocobalamin (B_{12})
	.... $mg\ kg^{-1}$			
Swine manure	2.21	6.49	1.13	0.31
CAF	2.46	3.06	1.68	0.12
SMF	2.35	4.34	1.89	0.40
AFS	1.39	9.33	2.56	0.76

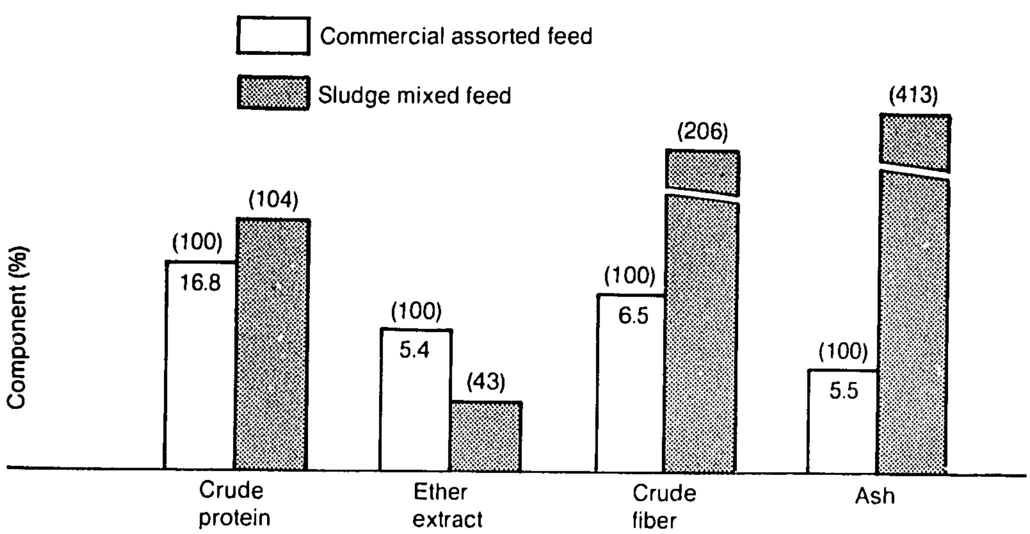

Figure 2. Nutrient Composition of Commercial Assorted Feed and Sludge Mixed Feed.

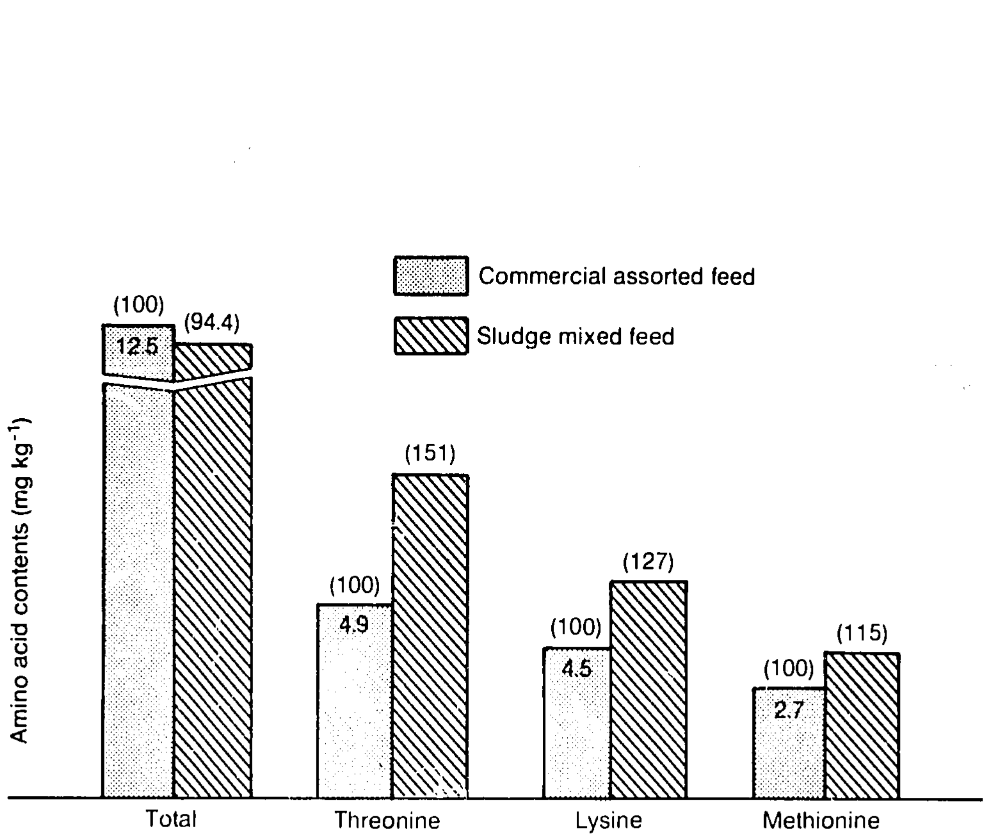

Figure 3. Essential Amino Acids Contained in Commercial Assorted Feed and Sludge Mixed Feed.

SMF was found to be lower in the ether extractable fraction and higher in crude fiber and ash than CAF. But there was no difference in crude protein for the two feed sources (Figure 2). The most notable difference was the higher content of threonine, lysine, and methionine in SMF compared with CAF. However, there was no difference in the total amino acid content for either feed source (Figure 3).

As shown in Table 5, the levels of riboflavin, pyridoxine, and cyanocobalamin were considerably higher in AFS than in swine manure. However, the thiamine content was lower for AFS than the manure. These results suggest that anaerobic fermentation of swine manure promoted the synthesis of substantial amounts of the B-complex vitamins, except for thiamine.

As shown in Table 6, the feeding of swine with SMF caused a slight depression in live weight of animals compared with CAF. However, the thickness of the fat layer of swine fed with SMF was 1 cm less than that of swine fed with CAF. Nevertheless, using SMF as a feed source for swine reduced the production cost by about 20 percent which is a significant economic benefit.

Solutions to Problems of Pollution

Developing anaerobic digestion technology is also an effective way of treating animal wastes and improving health standards in the rural areas. Swine manure subjected to anaerobic digestion for only one month can achieve the following reduction in pathogen levels: ascaris, 100 percent; trichuris, 96 percent; E. coli, 99.8 percent; and enterococcus, 96.8 percent (Table 7). Furthermore, it can abate offensive odors in the manure.

The purity of water is generally determined by the amount of organic matter that it contains in terms of BOD and COD. Clean water should have a BOD level of less than 3 ppm. Anaerobic digestion can reduce BOD, COD, and volatile solids by 92, 68 and 78 percent, respectively (Table 8).

The hydraulic retention time of the substrate was greatly related to BOD reduction. The longer the substrate was held in the digester, the higher the BOD reduction.

Table 6. Effects of Commercial Assorted Feed and SludgeMixed Feed on Live Weight, Feed Consumption and Fat Thickness of Swine.

Parameter	Commercial Assorted Feed	Sludge Mixed Feed
Live weight, kg	108	100
Gain of body weight, kg	88	80
Feed consumption, kg	304	280
Back fat thickness, cm	3.2	2.3

Table 7. Kill Rate of Pathogens by Anaerobic Digestion.

Organisms	Influent	Effluent	Kill Rate
			%
Ascaris, EPG†	200	-	100
Trichuris, EPG	2500	100	96
E. Coli, CFU ml^{-1}‡	445	77	99.8
Intestinal coccus, CFU ml^{-1}	128	40	96.8

†EPG: Eggs per gram of feces.
‡CFU ml^{-1}: Colony forming units per ml.

Table 8. Average Concentrations and Percentage Reduction Pollutants from Anaerobic Digestion of Swine Manure.

Pollutant	Influent	Ist Effluent	2nd Effluent
BOD, ppm	20,600	2,450 (88.1%)	1,650 (92.0%)
COD, ppm	65,400	38,100 (41.7%)	20,700 (68.4%)
VS†, %	6.92	3.5 (49.5%)	1.55 (77.7%)

†Volatile solids.

Conclusion

Currently, there are serious pollution problems in the rural areas of Korea that are associated with the dramatic increase in numbers of livestock, particularly cattle and swine, and inadequate methods of manure disposal.

A promising solution to this problem is the use of anaerobic digestion technology on farms which can convert animal manures into high energy fuel (biogas), and into useful fertilizer and livestock feed. This technology can also improve the health standards of rural people because it greatly reduces the levels of pathogens in the digested sludge and slurry, and abates offensive odors.

Recent Developments in Alternative Agriculture in the United States

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ABSTRACT. During the four decades following World War II, the U.S. agricultural production system became highly mechanized and specialized, and dependent upon fossil-fuel energy, chemical fertilizers, and pesticides. The 1980 USDA Report and Recommendation on Organic Farming found that because of the economic, social, and environmental concerns created by these farming practices, many farmers began shifting away from conventional, chemical-intensive farming systems to a less intensive approach based on sod-based rotations and mixed crop-livestock enterprises. The changes that have occurred in the past 10 years on farms in the United States are discussed as are the concepts and terminologies of alternative or low-input, sustainable agriculture; the degradative processes and conservation practices that affect soil productivity; and the factors which affect crop quality and nutrition. Research needs and priorities are suggested.

Introduction

A recent book entitled *Alternative Agriculture* published by the National Research Council (1989) relates how agriculture in the United States was transformed from a predominately mixed crop-livestock farming system, based on crop rotations, to highly specialized cash grain and confined livestock operations. It describes how this has led to many of the current problems we face including excessive soil erosion, ground water pollution by agrichemicals, and doubts by consumers about food safety and quality.

At the end of World War II most farms in the United States were mixed crop-livestock operations. Farmers produced forages and feed grains for their animals through long-term crop rotations which required minimal purchased inputs, including chemical fertilizers. Soil productivity was maintained by crop rotations including nitrogen-fixing legumes, and the return of crop residues and animal manures to the land. Few pesticides were used. Weeds, insects, and plant diseases were controlled through crop rotations, mechanical cultivation, and biological means such as natural predators.

Following World War II, United States' agriculture became more specialized and dependent on purchased off-farm inputs of chemical fertilizers, pesticides, energy, and credit. Government programs and farm subsidies reduced the risk of specialization which encouraged the separation of the livestock component from feed grain production. This resulted in the decline of two very vital soil and water conservation practices, i.e., the return of animal manures to the land and the rotation of grain crops with grasses and legumes. Consequently, farmers that specialized only in cash grain production, often monoculture systems, then had to increase their inputs of chemical fertilizers and pesticides to compensate for the lost benefits of crop rotations. Thus, for most of four decades U.S. agriculture has substituted machinery, pesticides, chemical fertilizers, irrigation, and energy for diversity, labor, land, and good management as the principal components of agricultural production.

Meanwhile during the same time, livestock production shifted toward large-scale feedlot confinement which required increased use of antibiotics and assorted vaccines to suppress diseases. Another consequence was that these feedlot operations created mountains of manure that had become the ultimate waste material which nobody wanted.

The capacity of U.S. agriculture to produce food and fiber in these highly specialized systems has been rather impressive even though there has been a steady trend toward fewer but larger farms. An often quoted statistic is that one U.S. farmworker currently produces food and fiber for about 78 people. Yet, despite this production capacity many of our farmers are going bankrupt because of the high cost of purchased inputs, low prices received for basic agronomic crops relative to the cost of production, inefficient methods of production, over-capitalization, poor management practices, and a high level of indebtedness.

Energy inputs in U.S. agriculture have escalated to the point where it takes three calories of energy input to produce one calorie of food output. Buttel and Youngberg (1982) estimated that the total energy input to output ratio for producing, transporting, processing, marketing, and preparing food for consumption in the U.S. is approximately 10 calories expended for one calorie of gain.

Consequently, for survival many farmers must focus strictly on intensive production of cash grain crops, e.g., wheat, soybeans, and corn, for short-term economic gain while essential conservation practices are largely neglected. Moreover, there is increasing evidence that excessive soil erosion associated with conventional farming systems is causing a significant loss of soil productivity.

Concern for the present structure of U.S. agriculture, i.e., highly specialized, large-scale, and capital- and chemical-intensive, and the economic, social, and environmental problems associated with it, caused former Secretary of Agriculture Bob Bergland to commission a team of scientists in 1979 to study organic farming methods and practices in the U.S. and abroad for possible alternatives. This paper discusses the results of that study and its impact on U.S. agriculture.

1980 USDA Report and Recommendations on Organic Farming

The U.S. Department of Agriculture's *Report and Recommendations on Organic Farming* (USDA, 1980) cited increasing concern among farmers, environmental groups, and the general public about the adverse effects of the U.S. agricultural production system, particularly the intensive monoculture of cash grains (wheat, soybeans, and corn) and the intensive and often excessive use of chemical fertilizers and pesticides. Among the concerns most often expressed to the USDA study team were:

1) Increased cost of, and dependence on external inputs of chemicals and energy;
2) Adverse effects of agricultural chemicals on human and animal health, wildlife, and on food safety and quality;
3) Decline in soil productivity from excessive soil erosion and nutrient runoff losses;
4) Contamination of surface and ground water from fertilizers and pesticides; and
5) Demise of the family farm and local marketing systems.

Because of these concerns, questions have been raised about the long-term sustainability of the U.S. agricultural production system, which has become so dependent on nonrenewable resources and exploitive of the natural resource base. The USDA Report found that many farmers, in addressing these concerns, had shifted away from conventional (chemical-intensive) farming systems to a less intensive, low-input approach based primarily on sod-based rotations and mixed crop-livestock enterprises.

The USDA Study Team found a broad spectrum of organic farming practitioners, ranging from purist or strict avoidance of synthetic chemicals on one extreme to a more liberal philosophy of selective use of chemicals as a last resort. To encompass the entire spectrum of organic agriculture, the USDA Study Team defined organic farming as:

> A production system which avoids or largely excludes the use of synthetically compounded fertilizers, pesticides, growth regulators, and livestock feed additives. To the maximum extent feasible, organic farming systems rely upon crop rotations, crop residues, animal manures, legumes, green manures, off-farm organic wastes,

mechanical cultivation, mineral-bearing rocks, and aspects of biological pest control to maintain soil productivity and tilth, to supply plant nutrients, and to control insects, weeds, and other pests.

A major conclusion of the Report was that these low-input farming systems are environmentally-sound, energy conserving, productive, profitable, and tend toward long-term sustainability. However, the organic farmers interviewed in the USDA case studies expressed the need for specific research and education programs that would benefit not only organic farmers but conventional farmers as well (USDA, 1980; Parr et al., 1983). These programs include:

1) Investigate organic farming systems using a holistic research approach to elucidate the interrelationships of organic waste recycling, nutrient availability, crop protection, energy conservation, and environmental quality.
2) Determine factors responsible for low crop yields during transition from conventional to organic farming.
3) Investigate the availability of phosphorus and potassium from low-solubility sources and their rate of release from soil minerals in organic farming systems.
4) Expand research on biological nitrogen fixation.
5) Develop more effective biological/nonchemical methods for control of weeds, insects, and plant diseases.
6) Establish curricula at agricultural universities on organic farming and alternative agriculture.
7) Develop educational/informational materials for extension agents on organic farming and alternative agriculture that would facilitate technology transfer to farmers.

Alternative Agriculture and Related Terminology

A number of terms and definitions have emerged in recent years that refer to a spectrum of low-chemical, resource- and energy-conserving, and resource-efficient farming methods. For example, words such as biological, ecological, regenerative, natural, biodynamic, eco-agriculture, and resource-efficient are specific terms used by certain advocates and groups to refer to various alternative agricultural production practices and technologies that, they feel, are essential to the development of long-term, sustainable farming systems. The more general terms that have come to be most widely used by the public during the last decade are alternative, organic, and low-input (Youngberg et al., 1984). Many of us in the United States who have been seeking alternatives to conventional agriculture tend to view the term *alternative* as one which encompasses most, if not all, of the others. The word *organic* would appear to come closest to being a generic term which represents these low-chemical, resource-efficient methods of farming. Thus, despite the reluctance of some to accept the term organic, particularly within the scientific community, its meaning is widely recognized and generally understood by a broad cross-section of the American public. The desire by certain advocates within the alternative agriculture community to find a term that is more acceptable to agricultural scientists may, in fact, help to explain the proliferation of these terms.

Our use of the term *alternative agriculture* is shown in Figure 1, which depicts a spectrum of farming methods as related to the use of synthetic agricultural chemicals. We have placed *organic farming* on the extreme left and associated it with nonuse of synthetic chemicals. *Low-input farming* seeks to reduce the amount of synthetic chemicals that are applied but allows for their limited use. This part of the spectrum is designated as alternative agriculture, with the remaining portion of the spectrum denotes conventional agriculture and unlimited use of synthetic chemicals.

Alternative Agriculture

Organic	Low-Input	Conventional
Non-use of synthetic chemicals	Limited use of synthetic chemicals	Unlimited use of synthetic chemicals

Figure 1. Alternative Agriculture Is Part of a Spectrum Which Includes Organic Farming, with Nonuse of Synthetic Chemicals, and Low-Input Farming Which Allows Their Limited Use.

The concept of alternative agriculture shown in Figure 1 was reinforced with publication of the book *Alternative Agriculture* by the National Research Council (1989). It states that

> Alternative Agriculture is *not* a single system of farming practices. It includes a spectrum of farming systems ranging from organic systems that attempt to use no purchased synthetic chemical inputs, to those involving the prudent use of pesticides or antibiotics to control specific pests or diseases. Alternative farming encompasses, but is not limited to, farming systems known as biological, low-input, organic, regenerative or sustainable.

Alternative agriculture is defined by the National Research Council (1989) as any system of food or fiber production that pursues the following goals:

1) More thorough incorporation of natural processes such as nutrient cycling, nitrogen fixation, and pest-predator relationships into agricultural production systems.
2) Reduction in the use of off-farm inputs with the greatest potential to harm the environment or the health of farmers and consumers.
3) Increased use of the biological and genetic potential of plant and animal species.
4) Matching appropriate cropping patterns to the productive potential and physical limitations of agricultural lands to ensure long-term sustainability.
5) Profitable and efficient production with emphasis on improved farm management and conservation of soil, water, energy, and biological resources.

Certification Standards for Organically-Grown Foods

During the last decade the term organic has evolved from its previous generic definition into one which has become widely used to develop certification standards for organically-grown foods. The demand for organic produce has increased significantly in the United States in recent years because of the public's concern about residual pesticides in food and possible adverse effects on human health. In a recent publication by the Center for Science in the Public Interest (Howell, 1989), it was reported that some 16 states have now passed laws or adopted regulations defining organic for labeling purposes. Such laws give consumers assurance that food labeled as organic was actually grown without the use of synthetic chemicals, especially pesticides.

Moreover, five states—Texas, Washington, Minnesota, New Hampshire, and Vermont—have developed inspection programs to certify that organic producers are actually in compliance with state certification standards and regulations. Most state regulations require that organic producers farm without synthetic agricultural chemicals for three years before they can claim their products are organically-grown.

Taxing Synthetic Agricultural Chemicals

Some states have become increasingly concerned about the pollution (both real and potential) of ground water by agricultural pesticides and fertilizers. This was evidenced in 1987 with passage of Iowa's Ground Water Protection Act. This Iowa State law authorized the taxing of all pesticides and synthetic nitrogen fertilizers sold within the state. This landmark environmental legislation provides $11 million through the taxation of agricultural chemical sales to support research and demonstration programs designed to reduce the use of synthetic chemicals in agriculture. Some $6.6 million of these funds were used to establish the Leopold Center for Sustainable Agriculture at Iowa State University to study alternative agriculture methods and to disseminate information to farmers, and another $1.3 million to study the effects of pesticides on human health. It is likely that other states will pass similar legislation in the future.

The Concept of Low-Input/Sustainable Agriculture

The word sustainable has become increasingly popular in describing different versions of alternative agriculture. According to Lockeretz (1988), "sustainable agriculture is a loosely defined term that encompasses a range of strategies for addressing a number of problems that afflict U.S. agriculture and agriculture worldwide." Such problems include loss of soil productivity from excessive erosion and associated plant nutrient losses; surface and ground water pollution from pesticides, fertilizers, and sediment; impending shortages of nonrenewable resources; and low farm income from depressed commodity prices and high production costs. Furthermore, sustainable implies a time dimension and the capacity of a farming system to endure indefinitely (Lockeretz, 1988).

In 1985, the U.S. Congress passed the Agriculture Productivity Act as part of the Food Security Act, Public Law 99-198 (otherwise known as the 1985 Farm Bill). This act provided USDA with the authority to conduct research and education in alternative agriculture, or, more specifically, on low-input or sustainable farming systems (USDA, 1988). For Fiscal Year 1988, Congress appropriated $3.9 million to implement the research and education programs requested in the Agriculture Productivity Act. This funding was increased to $4.5 million for Fiscal Year 1989.

The concept that has emerged from these initiatives is one of low-input/sustainable agriculture or LISA which is shown in Figure 2 (Personal communication from Dr. Neill Schaller, USDA-CSRS, Washington, D.C.). The ultimate goal of sustainable agriculture is to develop farming systems that are productive and profitable, conserve the natural resource base, protect the environment and enhance health and safety, and do so over the long-term. The way to achieve this is through low-input methods and skilled management which seek to optimize the management and use of internal production inputs (i.e., on-farm resources) in a manner that provides acceptable levels of sustainable crop yields and livestock production and results in economically profitable returns. This approach emphasizes such cultural and management practices as crop rotations, recycling of animal manures, and conservation tillage to control soil erosion and nutrient losses and to maintain or enhance soil productivity. Low-input farming systems seek to minimize the use of external production inputs (i.e., off-farm resources), such as purchased fertilizers and pesticides, wherever and whenever feasible and practicable; to lower production costs; to avoid pollution of surface and ground water; to reduce pesticide residues in food; to reduce a farmer's overall risk; and to increase both short- and long-term farm profitability.

Another reason for the focus on low-input farming systems is that sooner or later most high-input systems fail because they are not economically or environmentally sustainable. Thus in the United States, sustainable agriculture has settled in as the ultimate goal. How we achieve this goal will depend upon creative and innovative methods and practices that provide farmers with economically viable and environmentally sound alternatives in their farming systems.

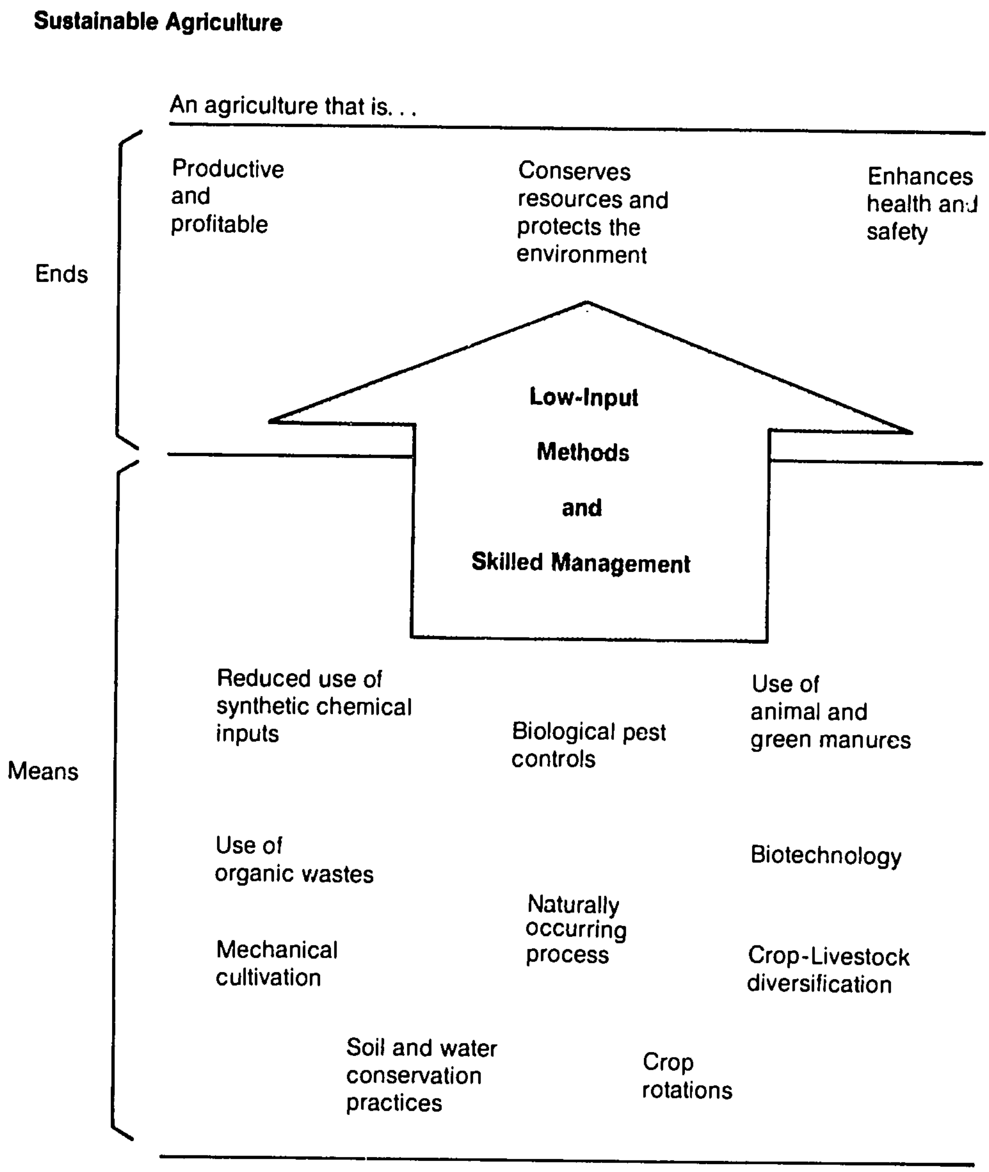

Figure 2. A Current Concept of Sustainable Agriculture in the United States Showing the Ends or Objectives and the Means of Achieving Them through Low-Input Methods and Skilled Management.

The Dynamic Nature of Soil Productivity

Soil productivity has been defined by the USDA (1957) as:

> The capability of a soil for producing a specified plant or sequence of plants under a defined set of management practices. It is measured in terms of outputs or harvests in relation to the inputs of production factors for a specific kind of soil under a physically defined system of management.

The key to alternative agriculture, or versions thereof, is soil productivity. An important relationship that is often overlooked is that for most agricultural soils, degradative processes such as soil erosion, nutrient runoff losses, and organic matter depletion are going on simultaneously with the beneficial effects of conservation practices such as crop rotations, conservation tillage, and the recycling of animal manures and crop residues.

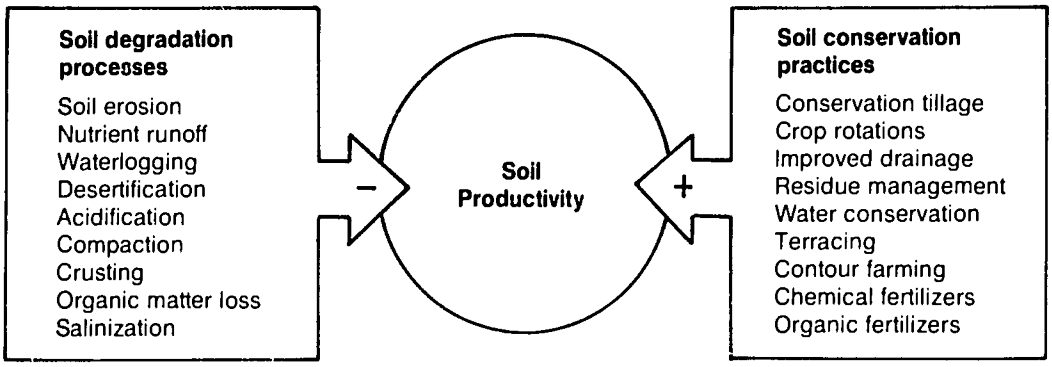

Figure 3. Relationship of Soil Degradative Processes and Soil Conservation Practices.

Thus, the potential productivity of a particular soil at any point in time is the result of ongoing degradative processes and applied conservation practices. This relationship is illustrated in Figure 3 (Hornick and Parr, 1987).

On our best agricultural soils, e.g. gently-sloping, medium-textured, well-structured, and deep, well-drained, a high level of productivity can be maintained by a relatively few, but essential conservation practices that can readily offset most degradative processes. However, on marginal soils of limited capability, e.g., steeply sloping, coarse-textured, poorly structured, nutrient-depleted, and shallow, poorly drained profile, soil conservation practices must be maximized to counteract further degradation. Organic wastes and residues offer the best possible means of restoring the productivity of severely eroded agricultural soils, or of reclaiming marginal soils (Hornick, 1982, Hornick and Parr, 1987).

Thus, the vital component in this dynamic equilibrium (Figure 3) is soil organic matter which must be maintained and replenished through regular additions of organic materials such as animal manures and crop residues (Parr and Colacicco, 1987) and composted municipal wastes (Hornick et al., 1984). The proper use of organic amendments is of utmost importance in maintaining the tilth, fertility, and productivity of agricultural soils, protecting them from wind and water erosion, and preventing nutrient losses through runoff and leaching.

Crop Quality, Nutrition, and Bioavailability

There are many factors that can affect crop quality. However, the cultivar and post-harvest handling probably have the greatest effect on the nutrient composition of crops. Cultivars are usually selected for their response to production inputs, especially chemical fertilizers, with maximum crop yields as the primary consideration (Hornick and Parr, 1987).

There has been much speculation on the benefits of consuming crops grown organically compared with those grown with synthetic chemical fertilizers. For example, researchers have shown conflicting results with respect to the ascorbic acid (Vitamin C) content of crops grown on soils amended with organic amendments as the sole source of plant nutrients compared with chemical fertilizers (Hornick and Parr, 1987). As farmers attempt to reduce their dependency on chemical fertilizers and pesticides, they will undoubtedly adopt various cultural practices to fulfill the plant nutrient requirement and to control weeds and insects. Thus, cultural practices could have a considerable impact on crop quality both now and in the future.

Recently, Hornick and Lloyd (1986) conducted studies to elucidate the effect of organic and chemical nitrogen sources on the ascorbic acid content of kale. They found that as the rate of inorganic nitrogen increased there was a progressive and significant decrease in the ascorbic acid content. These results indicate that increased nitrogen rates do tend to depress ascorbic acid levels of some crops. While this might be attributed in part to a dilution effect from increased yields, their work suggests that other biochemical interactions are involved.

The concept of producing better quality crops, however, is a complex issue because bioavailability of crop nutrients depends on many factors. Bioavailability refers to the amount of a particular nutrient that is absorbed from a food after consumption that is utilized by an animal or human. It is not the total amount of a nutrient in the food that is consumed.

Measurements of nutrient bioavailability are difficult because of the many interactions that occur between minerals, vitamins, and food components such as fiber. For example, iron bioavailability is determined by the iron status of the individual and the source of iron being consumed. It is enhanced by the presence of ascorbic acid (vitamin C) in the meal. In addition, iron bioavailability may decrease when a meal high in dietary fiber is consumed by an individual who does not normally consume a large amount of dietary fiber. Iron, ascorbic acid, and fiber are important in the diet for optimal health and normal bodily function. However, the ways in which they interact with one another will determine the health and well-being of an individual.

In addition to these types of interactions, little is known about the bioavailability of nutrients in crops grown under different management practices. It is apparent that research is needed to determine the effect of cultural and management practices on the nutritional quality of agricultural and horticultural crops, and on the bioavailability of nutrients of foods and feeds consumed by human beings and animals.

Research Needs and Priorities

The following areas of research should be given high priority by USDA, agricultural universities, and private organizations to promote the development of alternative farming systems.

1) Conduct research on low-input/sustainable agriculture using a systems or holistic approach. We need to know the chemical, physical, and biological interactions occurring in these systems and their relationship to organic recycling, nutrient availability, crop protection, energy conservation, crop quality, and environmental quality.
2) Assess the relative profitability of alternative farming systems compared with conventional agriculture.
3) Determine the reasons for decreased crop yields during transition from conventional to alternative farming systems so that farmers can avoid undue economic loss.
4) Conduct on-farm research in which the scientist, the farmer, and the extension agent work closely as a team in planning and implementing the research, and in interpreting the results.
5) Develop nonchemical methods and techniques for the control of weeds, insects and plant diseases.
6) Determine the nutritional quality of crops and the bioavailability of food nutrients for crops grown in alternative farming systems. This will be important as cultural and management practices change and as new cultivars are introduced.
7) Develop improved methods for on-farm composting of animal manures and crop residues.
8) Establish and assign proper nitrogen credits in calculating the nitrogen requirements for crops. Farmers need to know the potential availability of nitrogen from soil, irrigation water, legumes, animal manures, composts, and other organic amendments to avoid excess nitrate in the environment and ground water pollution.

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Section V

Experiments on Effective Microorganisms (EM)

The Concept and Theories of Effective Microorganisms

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ABSTRACT. A principal goal of nature farming is to produce abundant and healthy crops without the use of chemical fertilizers and pesticides and without causing adverse effects on the natural environment. One means of achieving this goal is through the use of effective microorganisms (EM). The benefits of EM in increasing crop yields, improving crop quality, and protecting plants from pests and disease have been demonstrated for a wide range of crops and soil conditions. The concept of EM is based on the inoculation of mixed cultures of beneficial microorganisms into soil where they shift the microbiological equilibrium and create an environment that is favorable to the growth and health of plants. A series of inoculations are made to ensure that the introduced microorganisms continue their dominance over the indigenous populations. The exact mechanism of how EM acts and interacts in the soil-plant ecosystem is not known. However, there is evidence that supports a number of theories concerning the action of EM. These include the suppression of plant pathogens and diseases, conservation of energy in plants, solubilization of soil minerals, soil microbial-ecological balance, photosynthetic efficiency, and biological nitrogen fixation. Future research will help to verify these hypotheses.

Introduction

The health of plants is affected by numerous biotic and abiotic interactions in soil and at root surfaces. This relatively unexplored aspect of plant biology is of considerable interest today because of the opportunity to apply biotechnological advances in exploiting beneficial microorganisms for enhancing plant growth and protection. This awareness has created some unique opportunities for the entrepreneur.

In conventional agriculture, chemical fertilizers, pesticides, and plant growth regulators are usually applied to increase the yield and quality of crops. However, the frequent and excessive use of these chemicals has often resulted in adverse environmental effects, disturbing the ecological balance of soils, and making plants even more susceptible to pests and diseases. In some cases, crop yields and quality have actually declined. In attempting to deal with this situation, scientists have focused on the development of high yielding plant varieties that are more resistant to pests and diseases.

The public has become increasingly concerned about the possible health hazards of chemical residues in food and the environmental pollution that has resulted from their use. Scientists themselves are asking such questions as: What are the differences in chemical, physical and microbiological properties of soils treated with agricultural chemicals and untreated soils? Can we farm successfully without the use of chemical fertilizers and pesticides? What are the alternatives to chemical-intensive conventional farming?

It has long been known that regular additions of organic amendments to soil, including crop residues, animal manures, green manures, nightsoil, and composted organic wastes, can markedly improve soil productivity, fertility, and tilth. It is also known that such amendments can significantly increase the numbers of beneficial microorganisms in the soil. For many years scientists have investigated the beneficial effects of their activities such as biological nitrogen fixation, organic matter decomposition, mineralization, nitrification, antagonism (to soil borne plant pathogens), and fermentation.

Since 1980, Professor T. Higa has been exploring alternative methods for a more sustainable agriculture in his investigation of the unique characteristics of some beneficial microorganisms that he collectively calls effective microorganisms or EM. Professor Higa has promoted the term natural farming or nature farming which is not simply farming without chemical fertilizers and pesticides; but rather it is organic farming with the added dimension of exploiting beneficial microorganisms to enhance soil quality and soil health. According to Professor Higa (1988), soils that are treated with effective microorganisms become disease-suppressive soils, zymogenic soils, and synthetic soils.

The development and application of EM has raised a number of questions and theories on the role of beneficial soil microorganisms in agriculture. This paper discusses the concept of EM and some of the theories of how EM may be affecting the soil and plant environment.

The Concept of Effective Microorganisms

From his study of beneficial microorganisms, Professor Higa concluded that the introduction of mixed cultures of microorganisms to soils and plants would likely be more effective, and for a longer period of time, than pure cultures. In due course, he developed three such mixed cultures of beneficial microorganisms that he found to be particularly effective. A mixed solution culture of photosynthetic bacteria, ray fungi, yeasts, and fungi, consisting of 10 genera and 80 different species he called EM 2. A mixed culture of photosynthetic bacteria is called EM 3. A mixed culture of *Lactobacillus*, and other microorganisms producing lactic acid, is called EM 4.

Experiments with the EM cultures have shown that both soil and foliar applications of EM can increase the yield and quality of various horticultural crops. For example, EM was found to significantly increase the content of vitamin C and sugar in fruit over that of the control. Today, EM is distributed under a registered trademark, and widely used on agricultural and horticultural crops in Japan including mango, tomato, spinach, brassica, allium, green pea, rice, cucumber, melon, and strawberry.

Theories of Effective Microorganisms

How can the application of EM to soil increase the yield and quality of crops? How does EM protect plants from pathogens and disease? Can disease-suppressive soils, zymogenic soils, and synthetic soils be induced by the application of EM? To answer these and other questions concerning the mechanisms of how EM acts and interacts in the soil-plant environment, it may be helpful to consider the following theories.

Disease-Suppressive Soil Theory

The term disease-suppressive soil refers to the biological means of suppressing the occurrence of plant diseases. Three examples of disease-suppressive soil are: (1) the pathogen fails to become established, (2) the pathogen is present but fails to cause disease and (3) the pathogen causes disease but declines with monoculture.

Figure 1 shows that the application of EM cultures to soil increased the yield of green pea over that of a fertilized control for three successive crops. Figure 2 shows that EM treated soil increased significantly in total numbers of fungi which, in turn, suppressed the incidence of plant pathogenic *Fusarium*. Other experiments have shown that soil treated with EM 2.3.4 had a lower incidence of plant fungal diseases (*Thielaviopsis* and *Verticillium*) and bacterial diseases (*Xanthomonas, Erwinia, Agrobacterium* and *Pseudomonas*) than the fertilized control. The suppression of plant pathogens and disease incidence is dependent on soil conditions, the plant, and which EM culture or combination of cultures is applied. This indicates that EM can induce a soil to become disease-suppressive in nature.

Organic Energy Theory

In the conventional theory, organic materials added to soil undergo decomposition by microorganisms, and minerals (nutrients) are released and become available for uptake by plants. In the organic energy theory, organic amendments are fermented by species of *Lactobacillus*, and other lactic acid producing microorganisms. This, in turn, releases amino acids and saccharides as soluble organic compounds that are absorbed intact by plants to be utilized beneficially in various metabolic pathways. Kinjo (1990) found that the amount of amino acid produced after incubation of organic matter with EM for five days was significantly higher than the control without EM. The absorption of amino acids, sugars, and other organic compounds by plant roots has been demonstrated in plant tissue

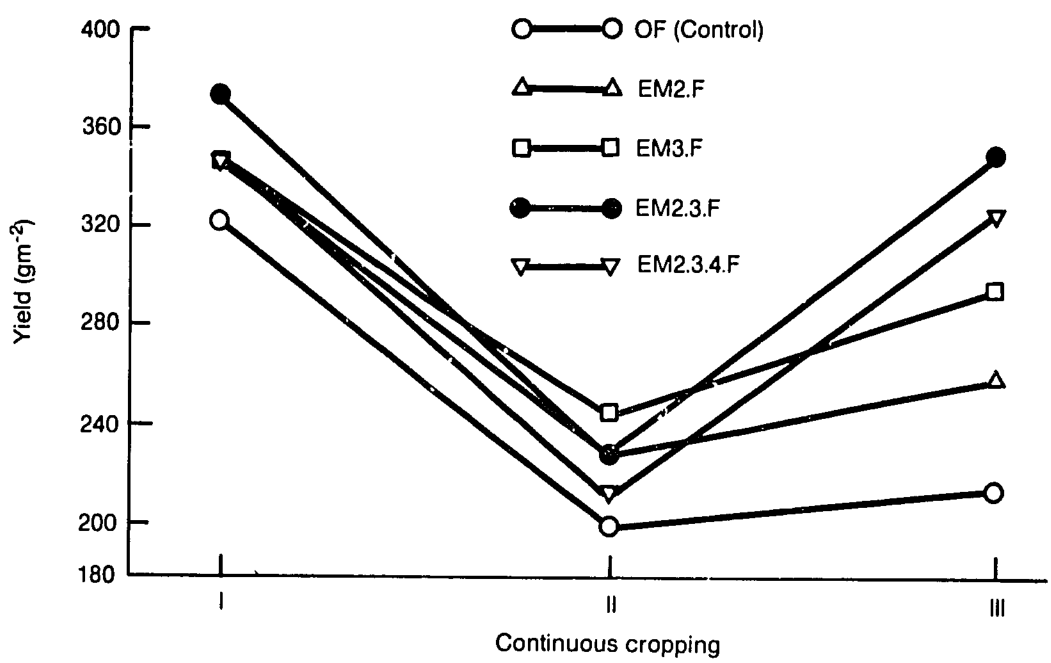

Figure 1. Effect of EM and Chemical Fertilizer on Green Pea Production.

OF: Chemical Fertilizer (Control)

EM 2F: EM 2 and Chemical Fertilizer

EM 3F: EM 3 and Chemical Fertilizer

EM 2.3F: EM 2.3 and Chemical Fertilizer

EM 2.3.4F: EM 2.3.4 and Chemical Fertilizer

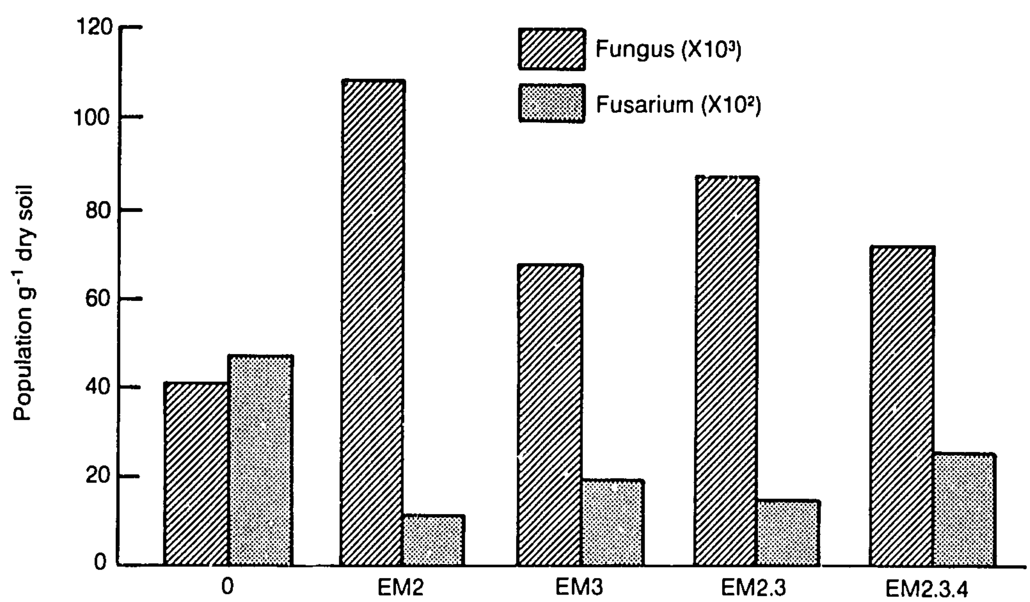

Figure 2. Effect of EM and Chemical Fertilizer on Soil Fungus and Fusarium population.

culture. Such work indicates that the plantlet, callus, or plant cell requires not only macro and micronutrients, but can also benefit from absorption of energy-yielding organic molecules such as amino acids and simple sugars.

The fermentation process is often utilized in the preparation of foods such as miso (soybean paste) and soy sauce, and in making silage for livestock. However, fermentation in soil and how it benefits the plant has been studied very little.

Inorganic Nutrient Solubilizing Theory

Soil microorganisms are important in decomposing organic materials and recycling their nutrients for uptake by plants. Soil productivity generally decreases as soil organic matter decreases (often through soil erosion and insufficient return of organic wastes and residues to land). When this happens, the total soil microbial population and its biodiversity also tend to decrease.

Experiments were conducted in which a 0.1% aqueous solution of molasses was applied to soil and to leaf surfaces of turnip *(Brassica rapa)* and green pepper *(Capsicum sp.)* as a carbon and energy source for indigenous microorganisms. The results showed a significant increase in the number of bacteria, actinomycetes, and fungi in both soil and on leaf surfaces over that of the unamended control (Tables 1 and 2). The foliar-applied molasses also caused a substantial increase in the numbers of nitrogen fixing bacteria on the surface of turnip leaves (Table 2). The yield of both green pepper and turnip was significantly increased by the association of the increased number of microorganisms (Table 3).

Insoluble organic phosphorus compounds that are largely unavailable to plants can often be solubilized by microorganisms. Similar results were obtained in an experiment where various EM cultures were added to soil. As shown in Figure 3, there was a substantial increase in inorganic phosphorus (P_2O_5) due to EM compared with the unfertilized control.

Balanced Population of Soil Microorganisms Theory

The incidence and severity of plant diseases depend on soil conditions, i.e., chemical, physical, and microbiological properties; soil management, i.e., tillage, fertilizers, and pesticides; crop management, i.e., crop rotation, monoculture, and multiple cropping; and the plant cultivar, i.e., disease-susceptible and disease-resistant. These factors can greatly influence the total microbial population, and its complexity and diversity, in soil. The balance in population and diversity between harmful and beneficial microorganisms will determine the soil microbiological equilibrium, and whether the soil ecosystem is favorable or unfavorable to the growth and health of plants. Generally, soils which have high

Table 1. Effect of Molasses Spray Applied to Soil on Numbers of Microorganisms.

Microbial Group	Dilution	Number of Microorganisms† Control	Molasses (0.1%)
Fungi	10^3	44.4	102
Fusarium	10^2	102	413
Bacteria	10^6	252	407
Actinomycetes	10^6	2.51	3.51

†Numbers per g of soil (dry weight basis). Microorganisms were counted in soil that was planted to green pepper.

Table 2. Effect of Foliar-Applied Molasses Spray on Numbers of Microorganisms on the Leaf Surface of Turnip.

Microbial Group	Dilution	Number of Microorganisms† Control	Molasses (0.1%)
Fungi	10^2	12.4	63.3
Fusarium	10^2	8.42	14.0
Bacteria	10^4	3.89	8.90
Actinomycetes	10^4	2.46	9.21
N Fixing Bacteria	10^3	1.42	10.3

†Numbers per g of soil (dry weight basis). Microorganisms were counted on the leaf surface of Turnip.

Table 3. Effect of Foliar-Applied Molasses Spray on the Yield of Green Pepper and Turnip.

Treatment	Green Pepper	Turnip
	g m⁻²	*g m⁻²*
Control	748	3660
Molasses (0.1%)	964†	4140†

†Significant difference between treatments at 5% probability by Duncan's test.

populations of actinomycetes, *Trichoderma*, *Penicillium*, fluorescent pigment-producing *Pseudomonas*, and other microorganisms that are antagonistic to plant pathogens, are considered to be disease-suppressive soils. Those which have large numbers of *Lactobacillus* and other fermentative microorganisms (yeasts, starch digesting bacteria, and cellulose digesting bacteria) are considered to be zymogenic soils. Soils which have large numbers of nitrogen fixing bacteria *(Azotobacter, Beijerinckia, Derxia,* and *Spirillum),* facultative anaerobic bacteria *(Bacillus, Enterobacter, Klebsiella,* and *Clostridium),* and photosynthetic bacteria are classified as synthetic soils. When a soil has high populations of plant pathogenic fungi *(Fusarium, Thielaviopsis, Phytophthora, Verticillium* and *Pythium),* it is considered to be a disease-inducing soil.

Photosynthetic and Nitrogen Fixing Theory

When EM are applied to soil or plant leaf surfaces, the populations of photosynthetic bacteria and nitrogen fixing bacteria increase dramatically. This phenomenon is associated with the growth of more vigorous plants, higher plant yields, and improved crop quality

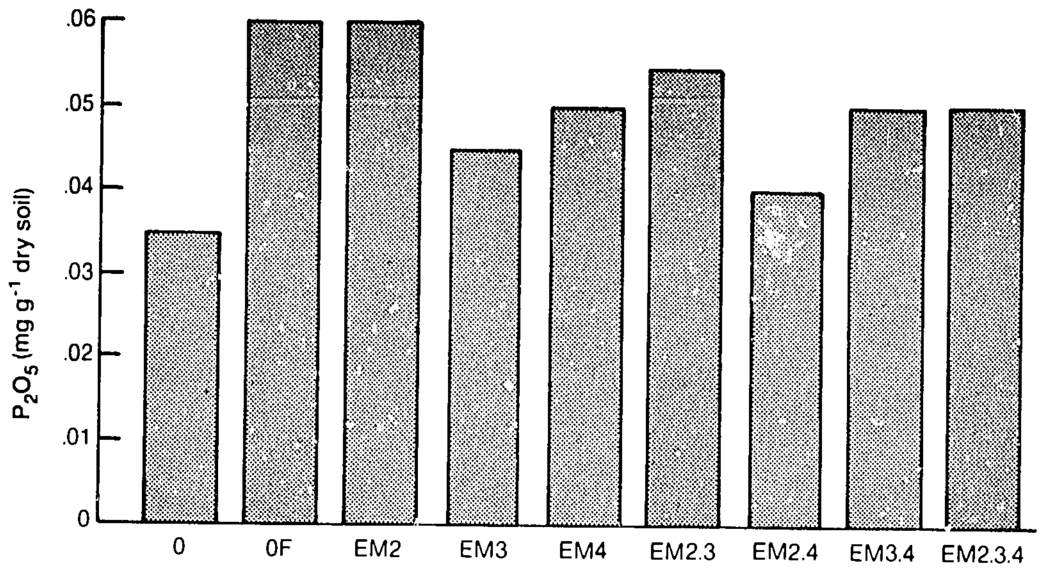

Figure 3. Effect of EM treatment on Soil P_2O_5 Content.

(based on higher contents of vitamin C and sugar in fruits) compared with no EM treatment. It was thought that the high number of photosynthetic bacteria and nitrogen fixing bacteria in soil and at leaf surfaces might enhance the plant's photosynthetic rate and efficiency, and its nitrogen fixing capacity. However, this has not been established experimentally. In this regard, Reid (1979) found that the net photosynthesis of *Pinus ponderosa* and *P. flexilis* tended to increase as the extent of infection by ectomycorrhizae increased.

Ruinen (1970) was among the first to investigate the occurrence of nitrogen fixing bacteria on leaf surfaces. Pati and Chandra (1981) and Sen Gupta et al. (1982a; 1982b) reported that nitrogen fixing bacteria on leaf surfaces could markedly increase crop yields.

Questions Concerning the Scientific Validity of Effective Microorganisms

There are those who doubt whether it is possible to introduce microorganisms into the soil-plant environment and actually shift the microbiological equilibrium in such a way as to derive beneficial effects on plant growth and yield. They say that this is possible only in the case of legume seed inoculation with *Rhizobium* species in which very large numbers of bacterial spores are placed on the seed coat to ensure survival and root infection. Moreover, most microbiologists are aware that early attempts to inoculate beneficial microorganisms into soils were made with single applications using pure cultures which consistently failed to elicit the hoped for beneficial response. The reason for this is that the introduced microorganisms would soon die out in a hostile or unfavorable soil environment.

Whether or not it is scientifically valid to inoculate a soil with a mixed culture of microorganisms, one needs only to consider such acceptable practices as adding animal manures, crop residues, and green manures to agricultural soils. All of these organic materials are colonized by populations of beneficial microorganisms that are not indigenous to soils but can, indeed, shift the soil microbiological equilibrium (at least temporarily) in ways that enhance crop yields and plant protection. A refined version of this is using EM to introduce mixed cultures of beneficial microorganisms into the agroecosystem, and to ensure their optimum effect through periodic and repeated applications.

Certainly there are unanswered questions concerning the actual mechanisms of how EM acts and interacts in the soil-plant environment, and the effectiveness of EM under conditions of soil and plant stress (e.g., severe drought, high soil temperatures, and soil nutrient deficiencies). Considerable research is now underway in a number of Asian and Pacific countries to answer these questions which should enhance the scientific validity of EM now and in the years to come.

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Nature Farming in Taiwan: Effect of EM on Growth and Yield of Paddy Rice

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ABSTRACT. The highly intensive farming systems in Taiwan have come to depend on heavy applications of chemical fertilizers and pesticides. This has led to serious environmental pollution problems and gradual sterilization of arable land.

Preliminary experiments with Kyusei Nature Farming in various districts of Taiwan prove that by utilizing effective microorganisms (EM) arable land is visually fortified and revitalized, enhancing plant health and improving the growth and yield of paddy rice. Microbial control farming offers the best means of achieving high production without polluting the environment.

Introduction

Along with the increased income per capita, people are seeking higher quality for their daily life. Recently, pesticide residues on vegetables and environmental pollution caused by industrial wastewater have resulted in serious problems for society (Fang and Wu, 1989).

Most naturally-occurring or synthetic organic materials are decomposed through microbiological processes. Therefore, it is appropriate to devote more effort to research on microorganisms to resolve the problem of environmental pollution.

Microbial Control: The Best Option for Pest Control

It is a natural rule that all creatures must eventually become sick and die, including human beings and insects. This rule keeps all creatures living in a balanced condition without overloading. Human beings have struggled for centuries against insects for their production of food. Chemical pesticides became an effective way of controlling diseases and insects. However, side effects of such chemical applications have created unexpected problems in past years, i.e., hazardous pesticide residues in food, poisoning of nontarget beneficial species, environmental pollution, and occurrence of antibiotic pests. Because of this, microbial control has been emphasized as a remedial measure to replace chemical fertilizers and pesticides (Liu, 1989).

Production Objective of Nature Farming

Nature farming is one of the most effective ways to avoid environmental pollution. Under this system, useful fertilizer is produced by allowing the primary resources to enhance the farming objectives. Meanwhile, entomopathogenic groups will be reduced or depressed, and the crop and land will be protected at less cost. No chemical fertilizers or pesticides will be used in the farming systems (Higa, 1987).

Promoting Nature Farming in Taiwan

The highly intensive farming methods practiced in Taiwan are dependent on heavy applications of chemical fertilizers and pesticides to sustain a high level of agricultural production. This has caused serious pollution problems and gradual sterilization of arable land (Liu, 1989).

It was indeed fortunate that Mr. Yasushi Matsumoto, President of Sekai Kyusei Kyo and his colleagues visited Chiuka-Minkoku Shin-Sei Sokai, Taipei, Taiwan in May of 1989. He asked Dr. Teruo Higa of the University of the Ryukyus, Okinawa, Japan, and Mr. Yoshikaza Arakawa of the International Nature Farming Research Center, Atami, Japan, to conduct a technical seminar on effective microorganisms (EM), and to teach our farmers how to use EM so as to avoid the application of chemical fertilizers and pesticides. We wanted to achieve a greater harvest at lower cost, and without the health hazards of pesticide residues on the crop. This would help us to achieve the objectives of Kyusei Nature Farming.

At the time of the visit, nature farming in Taiwan was only in the initial stage of development. However, under the aggressive promotion of the late Mr. Wu Huan-Shin, preliminary experiments were initiated to assess the effects of seasonal differences on crops in various regions. Thus, nature farming has officially been implemented, and the following results obtained.

Results of Nature Farming on Paddy Rice

The preliminary locations for testing the nature farming system for paddy rice are: 200 m^2 of sloping land at Tou-Sur, Nan-Tou Hsien, furnished by the President of the Judicial Yuan, his excellency, Mr. Lin, Yang-Kang; 80 m^2 of farmland at Shiao-Chia, Tainan Hsien, furnished by Mr. Lou, Hou-Chuan; and 300 m^2 of farmland at Shan-Hua, Tainan Hsien, furnished by Mr. Lin, Chin-Pao.

Results of EM on Control of Weeds

Generally, conventional farming systems apply chemical herbicides to control weeds after the seeding of crops and after seeding of paddy rice, in lieu of hand weeding or other mechanical control methods.

According to Dr. Teruo Higa, the innovator of the concept of effective microorganisms, EM can be used to treat farmland before seeding paddy rice, and thereby encourage the early germination of weed seeds. The germinated weeds are then fully in contact with EM and rake sowing can proceed. This ensures that all the weeds are covered by soil so that they can be decomposed and fermented by microorganisms and turned into humus. This, in turn, will increase the availability of plant nutrients in the soil (Higa, 1987).

In the EM treatment at Nan-Tou, Taiwan, the regrowth of weeds was not fully controlled. This was because we were not able to carry out the EM treatment properly before the seeding of paddy rice, but we did achieve more than 70 percent efficiency of control. An interesting phenomenon was discovered on the EM treated farmland, i.e., the regrowing weeds were more easily removed by manual labor than on land that was farmed with conventional methods.

Control of Diseases and Insects

Conventional farming usually applies pesticides to all types of insect infestation, and often good results are achieved. However, residual toxic chemical residues in agricultural products are creating a potential hazard to human health which is not acceptable to the consumer.

Because of the need for intensive agricultural production in Taiwan, it is almost impossible to leave farmland fallow or unplanted. Therefore, all types of diseases and insects are continuously infesting different crops.

In comparing nature farming with conventional farming, with respect to the control of disease and insect infestations, the major difference is that the pesticides are aggressive and instantly effective, but also directly and indirectly toxic.

EM is used to increase the initial resistance factor of the crop, and then to slowly cause a decline in the activity of harmful insects, thereby achieving the results of natural death. Therefore, it is predictable that the effect of EM is preventive rather than toxic.

Thus far, we have not been able to show effective inhibition of the disease-causing organisms *Thanatephorus cucumeris* (Frank) Donk and *Chilo suppressalis* (Walker). However, early and proper EM treatment has effectively inhibited such plant pests as *Rhizoctonia solani*, the mycoplasma-like organisms, *Tryporyza incertulas* (Walker), *Nilaparvata lugens* (Stal), *Cnaphalocrocis medinalis* (Guenee), and *Hydrellia sasokii* (Yuosa) (Table 1) (COAT, 1984).

Table 1. The Effects of Effective Microorganisms (EM) on Diseases and Insect Infestation Control in Paddy Rice.

Experiment Period : Jun. 22 thru Oct. 8, 1989

Date of Checking		6/22	6/29	7/22	7/29	8/02	8/12	8/19	9/02	9/16
Day after Seeding		1st Day	7th Day	30th Day	37th Day	41st Day	51st Day	58th Day	72nd Day	88th Day
Type of Disease	Group									
Rhizoctonia solani	EM-GP	–	X	X	X	–	–	–	–	–
	CK-GP	–	X	X	–	–	–	–	–	–
Mycoplasma-like organism	EM-GP	–	–	X	XX	X	–	–	–	–
	CK-GP	–	–	X	X	X	–	–	–	–
Thanatephorus cucumeris Donk	EM-GP	–	–	X	XX	XX	XXX	XXX	XX	XX
	CK-GP	–	–	X	XX	X	X	–	–	–
Chilo suppressalis Walker	EM-GP	–	–	X	XX	XX	XXX	XXX	XXX	XX
	CK-GP	–	–	X	XX	X	–	–	–	–
Tryporyza incertulas Walker	EM-GP	–	–	X	X	–	–	–	–	–
	CK-GP	–	–	X	–	–	–	–	–	–
Nilaparavata lugens (Stal)	EM-GP	–	X	XX	X	X	–	–	–	–
	CK-GP	–	X	X	–	–	–	–	–	–
Cnaphalocrocis medinalis Guenee	EM-GP	–	–	X	X	XX	XX	X	–	–
	CK-GP	–	–	X	X	XX	X	–	–	–
Hydrellia sasokii Yuosa	EM-GP	–	–	X	X	XX	XX	X	–	–
	CK-GP	–	–	X	X	X	X	–	–	–
Pyricularia oryzae Cav.	EM-GP	1st Day of Seeding						–	X	XX
	CK-GP	on Aug. 13, 1989						–	X	X
Xanthomonas campestinis Ishi.	EM-GP	1st Day of Seeding						–	–	X
	CK-GP	on Aug. 13, 1989						–	–	X
Nephotettix spp.	EM-GP	1st Day of Seeding						–	X	XX
	CK-GP	on Aug. 13, 1989						–	X	X

Remarks :

1/. At 7th day after seeding – EM 0.1% for EM group (EM-GP), Pesticide for Checking group (CK-GP) has been sprayed.
2/. At 36th day after seeding – EM 0.2% for EM-GP, Pesticide for CK-GP has been sprayed.
3/. At 41st day after seeding – EM 1.0% for EM-GP, Pesticide for CK-GP has been sprayed.
4/. At 52nd day after seeding – EM 1.25% for EM-GP, Pesticide for CK-GP has been sprayed.
5/. At 59th day after seeding – EM 1.50% for EM-GP, Pesticide for CK-GP has been sprayed.
6/. Average pH value is 7.3, and Temperature is 32 degree of C.
7/. '–' means infestation NIL, 'X' means primary infestation. 'XX' means serious infestation, 'XXX' means very serious.

Table 2. The Effects of Effective Microorganisms on the Propagation and the Growth of Paddy Rice.

Experiment Period : Jun. 22 thru Oct. 08, 1989

Day after Seeding	Average Numbers of Paddy Rice (pcs)		Height of Paddy Rice (cm)		Quantity of EM Treatment for EM Group
	EM-GP	CK-GP	EM-GP	CK-GP	
1st Day	8	6	11	9	0.1%
30th Day	11	13	18	16	0.1%
37th Day	13	16	34	31	0.2%
41st Day	16	21	39	34	1.0%
42nd Day	20	24	60	55	1.25%
59th Day	24	27	71	63	1.5%
73rd Day	24	27	100	73	–

Regression Output: (Buds)

Constant	9.160874
Std Err of Y Est	1.993146
R Squared	0.909369
No. of Observations	6
Degrees of Freedom	4
X Coefficient(s)	892.4037
Std Err of Coef.	140.8633

Regression Output: (Height)

Constant	14.98126
Std Err of Y Est	9.136979
R Squared	0.876995
No. of Observations	6
Degrees of Freedom	4
X Coefficient(s)	3448.491
Std Err of Coef.	645.7457

Results of Propagation and Growth of Paddy Rice

After the EM treatment, the germination and early growth of paddy rice was about the same as that planted with conventional farming methods. Later on, however, the rice plants receiving the EM treatment developed straighter stems and heavier leaves than plants grown by the conventional methods. Moreover, the EM treated plants developed a more extensive root system. Hence, despite the devastation to crops caused by Typhoon Sara in September 1989, the EM treated paddy rice was still straight and stems were neither bent nor broken. However, the conventionally-grown paddy rice was bent in every direction, with the leaves dropping down and the stems broken.

After treatment with EM, the flowering and fruiting of the paddy rice were 7 to 10 days earlier than rice grown with conventional methods (Table 2 and Figures 1 and 2).

Soil Improvement and Environmental Impact

According to Dr. Teruo Higa, after the EM treatment organic materials in the soil are decomposed by EM; the humus content is increased; the content and availability of nutrients are increased; the nitrogen cycling function of the soil is increased; and the soil oxygen content or volume is increased. Consequently, the physical nature of the soil has improved which enhances tilth, drainage, and a water-holding capacity (Higa, 1987).

These results, indicate that the EM treated farmlands are really more friable, less compact, and better drained than the conventionally farmed lands. Thus, the EM treated soils provided a more favorable environment for crop growth.

Another obvious difference was that the EM treated rice paddy had a great number of phytoplankton and algae which spread throughout the paddy. This is indirectly beneficial to

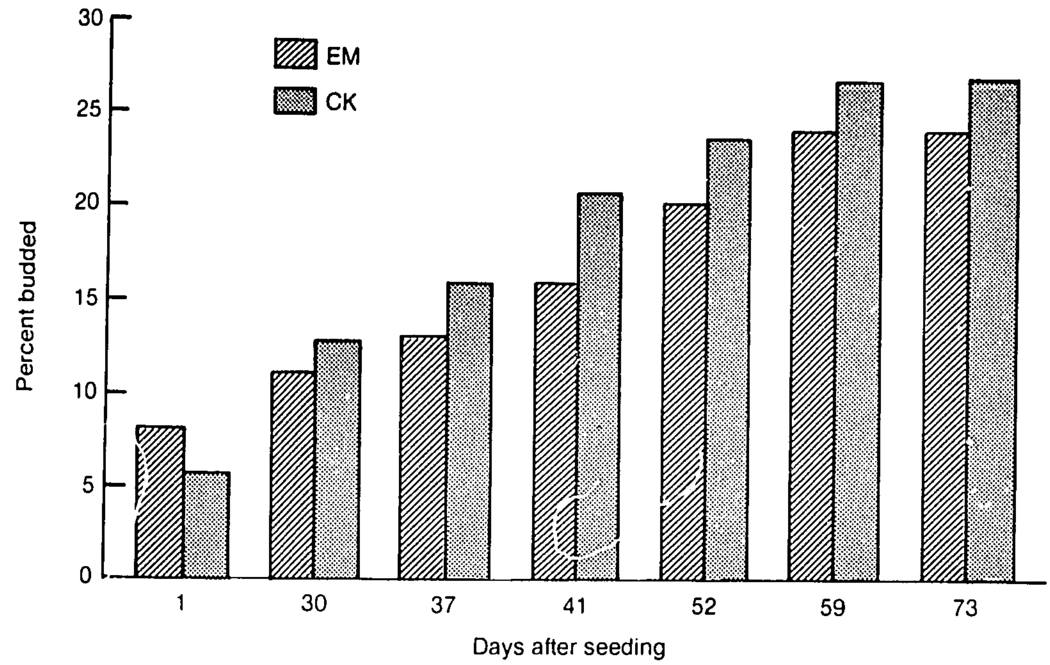

Figure 1. Budded Paddy Rice.

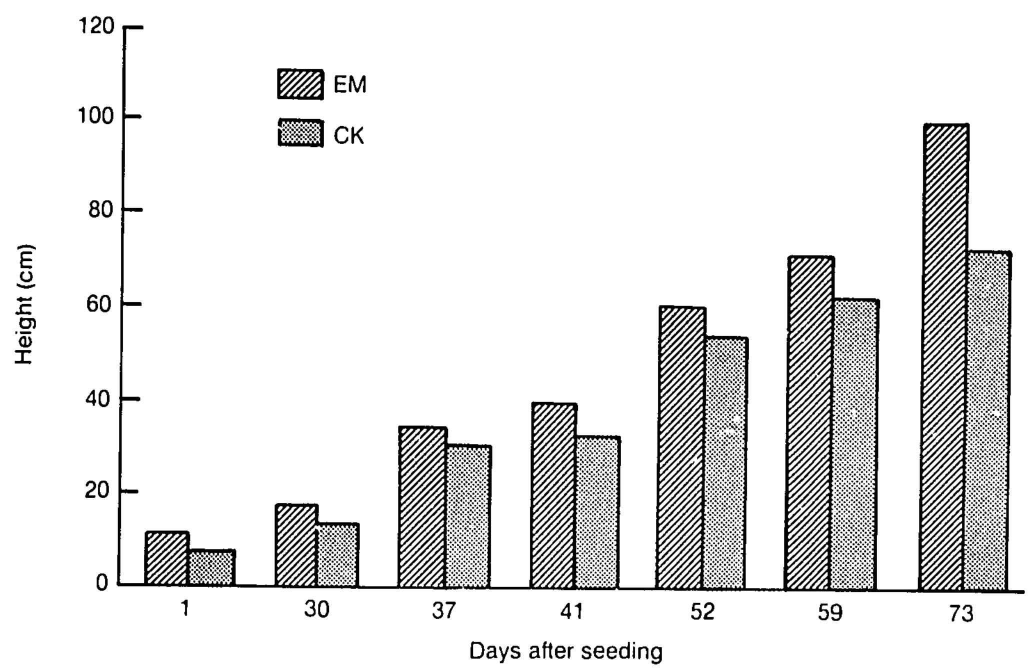

Figure 2. Height of Paddy Rice.

the growth of paddy rice. It is noteworthy that the conventionally-farmed paddy did not have noticeable growth of phytoplankton.

As for the environmental pollution impacts, because the EM treatment replaces conventional cultivation's use of chemical fertilizers and pesticides, there is no concern about residual toxicity in the paddy rice. Also, the propagation and growth of paddy rice are more suitable. It is easy to obtain the sunshine and the ventilation of air which accelerates the growth of paddy rice. Meanwhile the soil quality and air quality are greatly improved.

Harvest of Paddy Rice and Future Outlook

According to Dr. Teruo Higa, studies on the nature farming method have shown that during the first year, the production of crops following EM treatment is little different than that of the conventionally cultivated farmland. However, in the second or third year, the production of crops from nature farming and use of EM greatly exceeds that of the conventionally farmed land. Moreover, the quality of paddy rice is improved due to EM (Higa, 1987).

The first year tests conducted at Non-Tou, Taiwan on the implementation of the nature farming method, do not appear promising. The obvious reason is that the two diseases caused by *Thanatephorus cucumeris* (Frank) Donk and *Chilo suppressalis* (Walker) are still spreading. Consequently the harvest yields will be reduced.

As for the EM treated farmland, the inhibition of weed regeneration and removal of weeds will be key research subjects for the implementation of the nature farming method.

After EM treatment, research will also focus on how to avoid the occurrence of disease and insect infestations and which phases of the pathogen's life cycle can be controlled by EM. This research will be a high priority in the future implementation of successful nature farming in Taiwan. Hopefully, this will also help to decrease the cost of EM.

An analysis comparing the overall costs with those of conventional farming shall also be one of our priorities. But the nature farming method can undoubtedly prevent environmental pollution. As a matter of fact, all these effective microorganisms exist in the natural environment. All we are doing is increasing the numbers and activities of these beneficial microorganisms, to give them more opportunities to combat plant pathogens, insects, and disease. Moreover, the harmful insects cannot readily generate resistance to these microorganisms. While the physiological capability of these beneficial microorganisms varies, when applied as mixed cultures they can effectively suppress a wide range of harmful insects and plant pathogens.

After application to the rice paddy, these organisms will adapt to this environment and become an effective control mechanism, which will be widely spread by means of natural forces. They should also be effective over the long-term against insects that are harmful to human health (Tsai, 1988).

The EM formulations are not harmful to humans or other animals; therefore, they are safe to the user as well as to the consumer.

Conclusions

From the EM experiments conducted in Taiwan, the following conclusions were reached:

1) Kyusei Nature Farming is one of the most effective ways to prevent environmental pollution.
2) By utilizing effective microorganisms (EM), arable lands are fortified and revitalized, thereby enhancing the healthy and vigorous growth of paddy rice.
3) The EM treatment made the stems and the leaves of the paddy rice stronger, straighter, and heavier than conventionally grown rice.

4) In controlling disease and insect infestations, it is predictable that the effects of EM are preventive rather than toxic.

5) EM formulations are not harmful to humans or animals; therefore, they are safe to the user as well as to the consumer.

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Effect of EM on Growth and Yield of Corn

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ABSTRACT. Crop yields in Northeast Thailand are often limited by unproductive marginal soils, and erratic and insufficient rainfall. The soil factors that limit yields, such as low fertility, low water retention, low organic content, and soil crusting, can be largely overcome by regular additions of organic amendments which offer the best means of improving soil productivity. To further enhance the rehabilitation of these soils, there is a growing interest in the principles of nature farming and the use of effective microorganisms (EM).

Greenhouse and field experiments were conducted to determine the effect of EM cultures, organic waste materials, and chemical fertilizer on the growth and yield of corn. In the greenhouse study, corn yields were highest where soils were amended with composts that had been prepared by inoculation with EM 1 and EM 4. There was no significant yield increase from adding chemical fertilizers to these treatments. The field experiment showed no significant difference in corn stover yields from soils amended with animal manure and chemical fertilizer, either singly or combined, and sugarcane bagasse applied with EM 2, EM 3, and EM 4.

Introduction

Northeast Thailand is the largest region of the country, comprising about 170,000 km^2 (106 million rai), or one-third of the country. Its population is about 17 million which is one-third of the total population. Agricultural production in the Northeast is only 25 percent of the national average, and annual per capita income is the lowest in the country, or about 40 percent of the national average. This is mainly due to unproductive and infertile soils, and erratic and insufficient rainfall.

Most of the agricultural soils in the Northeast have moderate to severe limitations to crop production, including salinity, acidity, low fertility, and coarse-textured, sandy soils with low water-holding capacity. Saline soils occupy about 17.8 million rai, and are classified as slightly, moderately, and heavily salt-affected. Sandy soils comprise more than 17 million rai.

Most of the low fertile to moderately fertile soils in this region are sandy loams and loamy sands. They are very low in their clay (mostly kaolinite) and organic matter content. Consequently, these soils are low in their plant nutrient holding capacity and buffering capacity. Sandy soils with only a small amount of low activity clay cannot provide stable organo-mineral complexes. Uncombined forms of organic matter are often more susceptible to microbial attack and more dispersible into runoff water.

Infertile and unproductive soils can result from infertile parent material such as sandstone; excessive soil erosion and nutrient runoff losses; intensive tillage and cropping patterns; and insufficient use of chemical fertilizer and biofertilizers. Sandy soils derived from sandstone are generally coarse-textured, high in bulk density, low in cation exchange capacity, low in water-holding capacity, and subject to compaction and surface crusting. These poor physical properties are often associated with a very low soil organic matter content.

The best means of improving the productivity of these very marginal and infertile soils is through regular additions of organic wastes and residues supplemented with judicious amounts of chemical fertilizers. Organic amendments help to improve soil physical properties and the retention of plant nutrients in the soil-root zone where they can be used more efficiently by plants. Most farmers have traditionally applied animal manures to their soils to enhance and maintain their productivity, especially for rice and vegetable crops.

However, animal manure is not as available as it once was, due to smaller numbers of cattle. Consequently, farmers have had to look elsewhere for other sources of organic waste materials.

Last year Thai farmers imported about two million Mg of chemical fertilizers. While these materials are rather expensive, they can be very effective in increasing crop yields. However, there are certain disadvantages in using them since they can increase soil acidity, degrade soil structure, and pollute surface and ground water through runoff and leaching.

The Prospect of Nature Farming in Northeast Thailand

Nature farming may offer the means of overcoming many of the problems and constraints that farmers face in Northeast Thailand. The aim of nature farming is to enhance agricultural production without interrupting the natural ecosystem and without the use of chemical fertilizers and pesticides. Nature farming seeks to develop agricultural production systems that utilize the natural ecosystems to ensure pollution-free food products, and that conserve energy, reduce production costs, utilize resources efficiently, and revitalize agriculture in rural areas. The application of effective microorganisms (EM) to soil, particularly those which can enhance the release and availability of nutrients to plants, while reducing the incidence and destructive effects of plant pathogens, is a promising new research initiative.

Reasons for using EM in nature farming include:

1) To produce sufficient good quality food that is free of toxic chemicals and beneficial to human health.

2) To conserve soil, water, and energy in agroecosystems and prevent environmental pollution.

3) To develop productive and healthy soils through the proper utilization of organic amendments and other waste materials (OWM).

4) To reduce the dependence of farmers on chemical fertilizers and pesticides.

Properties and descriptions of the various EM formulations follow.

EM 1 has predominately filamentous fungi that are heat resistant and hasten the decomposition of organic amendments; is often more effective if applied with EM 4; and works best under aerobic conditions.

EM 2 is a mixture of more than 10 genera and 80 species of coexisting microorganisms (photosynthetic bacteria, ray fungi, yeasts, molds, etc.) that have been cultured in a liquid medium with a controlled pH of 7.0 and stored at pH of 8.5. [Number in saturated culture solution was 10^9 g^{-1}.] The mixture is predominately *Streptomyces* and can prevent diseases in plants; can enhance the effectiveness of *Azotobacter* and mycorrhizae; can transform a disease-inducing soil (e.g., one with high populations of *Fusarium*) into a disease-suppressive soil.

In EM 3, more than 95 percent of the microorganisms consist of photosynthetic bacteria which promote the transformation of soils into synthetic soils. It is effective for improving the quality of crops and for enhancing the effect of EM 2. The mixture is liquid at a pH of 8.5 and at a concentration of 10^9 organisms g^{-1}. EM 3 can make chemical fertilizers unnecessary and can effectively fix nitrogen, existing symbiotically with *Azotobacter spp.*

The EM 4 formulation has more than 90 percent of microorganisms such as lactobacilli that produce lactic acid. It can enhance the fermentation of organic materials and make them more soluble even under aerobic conditions. The mixture is liquid at a pH of 4.5 and at a concentration of 10^9 microorganisms g^{-1}. EM 4 accelerates the production of humus and can abate malodors of some organic materials in paddy fields.

Materials and Methods

What is needed to optimize the beneficial effects of effective microorganisms? All soil microorganisms, whether bacteria, fungi, or actinomycetes, require energy, nutrients, water, and optimum conditions of temperature, pH, and oxygen. Organic amendments are the principal sources of nutrients and energy and, thus, must be added to soils on a regular basis. The many beneficial effects of organic materials on soil productivity, fertility, and tilth are widely known.

We recently conducted two preliminary experiments with EM. One was a greenhouse study to determine the effect of EM in combination with different types of locally-available organic waste matter (OWM). The other was a field study to compare the effect of EM with different chemical fertilizers and biofertilizers, as well as lime. Both experiments used corn as an indicator crop.

Greenhouse Experiment

The objective of this experiment is to determine the effect of EM in combination with different types of locally-available OWM on the growth of corn.

Three kinds of OWM were used: corn cobs, peanut shells, and bagasse. Each waste material was mixed with cow manure, rice bran meal, rice husks, and rice husk ash. The mixtures were then divided into two parts, with EM and without EM, respectively. EM 1 was mixed into the compost pile, while EM 4 was diluted 1,000 times and watered into the heap at weekly intervals. After two months of curing for moisture, aeration, and temperature, each compost pile was sampled, weighed into three parts, and mixed (10% by weight) with the air-dried, sieved Korat soils (Oxic Paleustults). This provided the treatments for OWM alone, OWM with chemical fertilizer, and OWM with EM. The chemical fertilizer (15-15-15) was applied at a rate of 25 kg rai^{-1}, and EM 2.3.4 were diluted 1,000 times and applied to the EM-treated pots instead of water. Sweet corn was seeded into the pots on August 31 and later thinned to four plants per pot. Plants were grown for five weeks. Soil water content was kept between 60 to 80 percent of field capacity. No insecticides or pesticides were applied. The experimental design was a randomized complete block with three replications for a total of 60 pots, including fertilized and unfertilized controls. Plant height and weight were measured, and observations were made for growth. Soil samples were analyzed before and after the experiment. Plants also were analyzed for their nutrient content. The effects of EM, chemical fertilizer, and OWM were determined statistically. The experiment will be repeated under the same conditions to verify the initial results.

Field Experiment

The purpose of this experiment was to compare the effect of EM with other conventional types of fertilizer (both chemical and organic) and lime on the growth and yield of corn under field conditions. The Yasothon soil series (oxic paleustults) was used. Treatments included the control; manure (4 Mg rai^{-1}); lime (100 kg $Ca(OH)_2$ rai^{-1}); chemical fertilizer (50 kg rai^{-1} of 15-15-15); a combination of manure + chemical fertilizer; and bagasse (4 Mg rai^{-1}) with EM. Plot size was 6x10 m with 75x50 cm spacing. All materials (except EM) were applied to the soil before planting. Sweet corn was planted on July 11, 1989 and later was thinned to two plants per hill. For the EM with bagasse treatment, EM 2.3.4 solutions were diluted 1,000 times with water and applied to the bagasse-amended soil at two week intervals. No insecticides or pesticides were applied. Soils were sampled and analyzed before and after the experiment. Plants were measured for height and weight, and were analyzed for their plant nutrient contents. When fully mature, the corn ears were collected twice and the numbers of ears and their weights recorded. The experimental design was a randomized complete block design with three replications for a total of 18 plots. The effects of different treatments were statistically compared.

Results

Greenhouse Experiment

The properties of Korat soils shown in Table 1 indicate that they are typically sandy loams, often highly acidic, and very low in organic matter, CEC, plant nutrients, and water-holding capacity.

Table 2 shows the chemical properties of composts after two months and just prior to their incorporation into soils, and also properties of the original OWM. Peanut shell compost has a considerably higher nitrogen content than either the corn cob or bagasse compost. However, the phosphorus and potassium contents were highest in the corn cob compost. Treatments of the organic waste materials with EM 1.4 tended to narrow the C:N ratio of the composts.

Analysis of variance shows that there were significant differences between sources of OWM and fertilizer with and without EM 2.3.4, based on F values. However, the treatments involving EM 1.4 were not significantly different. For the OWM treatments plant dry weight means in grams were as follows:

Organic Waste	*Plant Dry Weight*
Peanut shells	10.3g a
Corn cobs	9.48g a
Bagasse	6.29g b
LSD (.05) = 0.81	

The sources of OWM from peanut shells and corn cobs resulted in significantly greater dry weights of corn than from bagasse.

The OWM treated with and without EM 1.4 were not significantly different.

The so-called fertilizer treatment which included a fertilized and unfertilized control compared with EM 2.3.4 also were significantly different. Plant dry weight means in grams were as follows:

Treatment	*Plant Dry Weight*
With fertilizer	9.83g a
With EM 2.3.4	8.28g b
Control (without fertilizer)	7.93g b
LSD (.05) = 0.8	

The fertilizer treatment gave the highest plant dry weight and was significantly higher than the EM treatment and the unfertilized control.

The four highest dry weight yields in grams were obtained from the following treatments, although there were no significant differences among them.

Treatment	*Plant Dry Weight*
Corn cob + EM 1.4 + F	12.1g a
Peanut shell + EM 1.4	10.4g ab
Peanut shell + EM 1.4 + EM 2.3.4	10.8g abc
Peanut shell + EM 1.4 + F	10.7g abc
LSD (.05) = 2.0	

Interestingly, the unfertilized and fertilized controls produced mean dry weights of only 1.5 and 2.8 g, respectively.

Table 1. Chemical and Physical Properties of Korat Soils Used in the Greenhouse Study and Yasothon Soils Used in the Field Study.

Soil Type	Particle Size Distribution Sand	Silt	Clay	Texture	pH	Bulk Density	Particle Density	Field Cap.	Wilting Point	Org. Matter	CEC	K	Ca	Mg	P
	.... %					$g\ cm^{-3}$	$g\ cm^{-3}$	%	%	%	....		*me 100* g^{-1}	....	*ppm*
Korat				Sandy loam	4.7	1.51	2.61	9.4	2.4	0.64	2.40	0.08	1.6	0.32	7
Yasothon	75	18	7	Sandy loam	4.9	1.50	2.60	7.2	2.8	0.46	3.25	0.09	0.45	0.20	10

Table 2. Chemical Analysis of the Compost and Original Organic Waste Materials.

Organic Waste Material	OC	N	C:N	P	K	Ca	Mg
	....	....	....	%	....	....	....
Composts†							
CC	14.6	0.71	20.5	0.32	0.57	0.52	0.29
CC+EM 1.4	13.6	0.71	19.2	0.30	0.51	0.44	0.26
PS	24.8	0.97	25.5	0.12	0.25	1.21	0.71
PS+EM 1.4	18.4	0.80	22.9	0.25	0.31	1.23	0.21
B	16.7	0.61	27.3	0.18	0.27	0.24	0.17
B+EM 1.4	20.6	0.88	23.4	0.42	0.49	0.37	0.31
Uncomposted							
B	37.5	1.13	33.0	0.16	0.32	1.81	0.11
CC	39.9	1.04	39.0	0.14	1.40	0.37	0.11
PS	37.7	1.27	30.0	0.08	1.00	0.31	0.12

† Composts included specific amounts of manure, rice bran meal, rice husks, and rice husk ash. Composts were produced primarily from corn cobs (CC), peanut shells (PS), and bagasse (B).

Field Experiment

Table 1 shows the chemical and physical properties of Yasothon soils. These soils are sandy loams in texture, acidic, low in organic matter, low in CEC, and moderate to low in their plant nutrient content. The bulk density is rather high and the water retention capacity is low.

The chemical properties of bagasse and manure used in the field experiment are reported in Table 3. Manure has a narrower C:N ratio due to its lower organic carbon but higher nitrogen content. Manure also contains higher amounts of most plant nutrients, a higher pH, and a higher CEC.

Table 4 shows the plant height, stover weight, and pod fresh weight from the different treatments. The treatment combination of organic plus chemical fertilizer ranked first for all parameters, followed by organic fertilizer or chemical fertilizer alone. For stover and pod weight, the bagasse plus EM ranked fourth, followed by the control and lime treatments, respectively. For stover, the bagasse plus EM treatment was not significantly different from any of the fertilized treatments. However, the pod weight was significantly higher for the combination of organic plus chemical fertilizer than for the other treatments.

Table 3. Chemical Analysis of Bagasse and Manure Used in the Field Experiment.

Organic Amendment	C:N	OC	N	P	K	C	Mg	pH	CEC
		.... %	....						$me\ 100\ g^{-1}$
Bagasse	33	37.5	1.13	0.16	0.32	1.81	0.11	-	17.5
Manure	23	28.7	1.22	0.30	0.61	1.30	0.21	7.9	26.1

Table 4. Plant Height, Stover Weight and Pod Fresh Weight of Corn from the Different Treatments.

Treatments	Height	Stover	Pod
	cm	$kg\ pot^{-1}$	$kg\ pot^{-1}$
OF + CF	161 a†	36 a	19 a
CF	154 a	28 a, b, c,	10 b
OF	150 a	29 a, b	11 b
Control	128 a	14 b, c	4 b
B + EM	123 a	26 a b, c	8 b
L	80 b	11 c	4 b
LSD (.05)	36	16	7
CV. (%)	15	30	40

† Column values followed by the same letter are not significantly different at the 5% probability level.

Summary and Conclusions

The low level of agricultural production in Northeast Thailand is due mainly to unproductive, marginal soils and erratic rainfall patterns. Many of the problems and constraints which limit production can be overcome by regular additions of organic waste materials to soil. This approach offers the best means of improving soil productivity. However, there is a growing shortage of good quality organic wastes that are available to farmers as soil amendments. Increasing concerns about the adverse effects of chemical fertilizers and pesticides on soil properties and the environment have generated considerable interest in the principles of nature farming and the use of effective microorganisms (EM) for developing more productive, stable, and efficient farming systems in the Northeast.

Greenhouse and field experiments were conducted to determine the effect of different combinations of EM formulations, OWM, and chemical fertilizer on the growth and yield of corn. In preparing experimental composts for a greenhouse pot study, it was noted that inoculation of the composting biomass with EM 1.4 narrowed the C:N ratio of the finished compost. The highest corn yields were obtained from soils amended with corn cob and peanut shell composts that had received EM 1.4. Interestingly, there was no significant yield increase from adding chemical fertilizer to these treatments, indicating that maximum yields were obtained from compost plus EM combinations.

The results of a field study indicated that a combination of animal manure and chemical fertilizer gave the highest values for plant height (corn), and the highest yields of stover and pod fresh weight. Of considerable interest is the fact that there was no significant difference in stover yields among treatments, including organic fertilizer and chemical fertilizer applied either singly or combined, and bagasse applied with EM 2.3.4. This suggests that the EM treatment enhanced the decomposition of bagasse and released available plant nutrients at a rate that could sustain the growth and yield of corn. Additional experiments are needed to verify these results.

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Effect of Lactic Acid Fermentation Bacteria on Plant Growth and Soil Humus Formation

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ABSTRACT. A study was conducted to determine if lactic acid bacteria, when inoculated into soil amended with organic materials, could enhance decomposition and the release of plant nutrients, and increase soil humus formation. The addition of EM 4 to soil amended with fresh green grass increased the growth of cucumber over that of the unamended and fertilized controls, while woodchips appeared to suppress growth. The yield of mustard and radish (tops and roots) were significantly higher with EM 4 at all dilution levels than either of the controls. However, mustard yield was highest at the 1:500 dilution, while there was little difference in radish yield for the dilutions used. Populations of fungi, lactobacilli, aerobic bacteria, and actinomycetes were generally higher in soil treated with EM 4 than for the unamended controls. Results indicate that EM 4 can accelerate the decomposition of organic amendments in soils and the release of their nutrients for plant growth. The soil humus content, even from addition of woodchips, was increased considerably from treatment with EM 4.

Introduction

Decomposition of organic matter in soil results in gas and heat production which are lost energy to the cultivated crop. This kind of decomposition can result in products that are harmful to plant growth (Gussin and Lynch, 1981). Nutrient recycling in terrestrial environments would be more efficient if this energy loss could be avoided. Fermentation pathways provide a more efficient means for utilizing organic substrates during their decomposition in soil.

Fermentation is a process that is often used in producing and preserving foods and beverages such as yogurt, cheese, and beer. In Japan, soy sauce (shouyu) and soybean paste (miso) are just two of many examples of fermentation. The fermentation process not only preserves foods from spoilage, but may even increase the nutrient value of the product.

Lactic acid fermentation bacteria are also responsible for the preservation of vegetable products for human consumption and silage for animals. There is some indication that lactic acid can inhibit the growth of microorganisms that are responsible for spoilage (Lynch, 1988). Nevertheless, high concentrations of lactic acid can provide good preservation (Langston and Bouma, 1960). Lactic acid bacteria have also been used for treatment of cattle manures and sewage for odor abatement, and as an inoculant to accelerate the composting of organic wastes (Okada, 1988).

The possibility of using this fermentation process in a soil environment has been of great interest. When green plant material is incorporated into the soil there is little loss of energy as gas and heat, and the phytotoxic effect that usually follows the decomposition of plant materials is minimized (Lynch, 1977).

The purpose of this study was to determine whether lactic acid bacteria inoculated into soil amended with different organic materials as substrates, could provide a more effective means for recycling plant nutrients and for increasing soil humus formation.

Materials and Methods

Experiment 1

A greenhouse pot experiment was conducted in October 1987 to determine the effect of EM on plant growth and soil humus formation. Soil was mixed with chopped crabgrass *(Digitaria ascendens* Henri) or woodchips at rates of 0, 0.5, 2.0, and 4.0 Mg 10 are^{-1} (10 are is 0.1 hectare), i.e., 0, 5, 20, and 40 Mg ha^{-1}, and placed in vinyl pots (20 cm diameter and 25 cm depth). Cucumber seeds were sown and EM 4 was applied to the soil each week at dilutions of 1:500, 1:1000, and 1:2000. EM 4 is comprised mainly (more than 90%) of *Lactobacillus* bacteria, but also contains photosynthetic bacteria, ray fungi, and yeasts. During the initial growth period, each pot received 45 mg of nitrogen, 25 mg of phosphoric acid, and 51 mg of potassium. Plant growth was recorded four times and soil samples were collected three times for analysis of NO_3-, NH_4+, pH, P_2O_5, K_2O, and humus.

Experiment 2

A greenhouse pot experiment was conducted in November 1988 in much the same manner as Experiment 1, except green (fresh) chopped rose grass was mixed with soil at a rate of 40 Mg ha^{-1}. Mustard seeds were then sown at 0, 1, 2, 3, and 5 weeks after addition of the organic amendment. A culture of *Lactobacillus plantarum* was applied to the pots each week at dilutions of 1:500, 1:1000, and 1:2000.

Lactobacillus plantarum (IFO 3070) was cultured at 30°C in GYP + 1% skim milk liquid medium (Okada, 1988); 1 ml of the culture contained approximately 1.2×10^9 bacteria. The culture was suspended in distilled water at a dilution of 1:10 and then further diluted, as previously described, for application to soil. Both fresh and dry weight crop yields were recorded. Soil microorganisms were enumerated by the plate count method using modified GYP agar (Okada, 1988) for lactobacilli; egg albumin agar (Tadao, 1984) for aerobic bacteria; rose bengal agar (Martin, 1950) for fungi; and a selective media (KenKnight and Muncie, 1939) for actinomycetes. The soil was analyzed initially and upon completion of the experiment for pH, K_2O, P_2O_5, NO_3-, NH_4+, and humus content.

Experiment 2b

A second experiment was conducted in March of 1989 with the soil that had been used in Experiment 2. The potted soil was amended with fresh green plant material from wild marigold (*Wedelia trilobata* Hitchc.) at a rate of 20 Mg -1 and radish seeds were sown. The *Lactobacillus* culture was applied to the pots at the same dilutions and frequency as in Experiment 2. Methods for enumerating soil microbial populations and soil analysis were the same as in Experiment 2.

Results

Experiment 1

As shown in Table 1, amending soil with green (fresh) chopped organic material resulted in better growth (height) of cucumber plants than from incorporation of woodchips, especially at the higher application rates of 20 and 40 Mg ha^{-1}. Inoculation of soil with *Lactobacillus* bacteria (EM 4) enhanced the growth of cucumber over that of the unamended and fertilized controls. Amending soil with woodchips appeared to suppress the growth of cucumber particularly at the highest rate of incorporation (40 Mg ha^{-1}) as shown in Tables 1 and 2.

There was little difference in the chemical analysis of soils among the treatments. However, at the end of the experiment the humus content was considerably higher in soil that had been amended with organic materials and inoculated with lactobacilli from EM 4 (Figure 1).

Experiment 2

Yield of mustard (biomass) was highest, and approximately the same, for the control pots that were amended with 40 Mg ha^{-1} of green (fresh) chopped rose grass, and those treated with EM 4 at a dilution of 1:500 (Figure 2). Yields from inoculation of soil with EM 4 at dilutions of 1:1000 and 1:2000 were somewhat lower.

Table 1. Effect of Soil Organic Amendments and Different Dilutions of EM 4 on Height of Cucumber.

Dilution†	Rate of Application‡						
	Control	Green Grass			Woodchips		
	0	5	20	40	5	20	40
	....	....	....	cm	....	....	....
Control (No EM)	91	111	140	133	72	86	49
1:2000	109	131	148	153	85	83	48
1:1000	114	129	146	143	92	81	49
1:500	129	126	136	136	94	67	55

† EM 4 dilutions were made from liquid stock culture that contained 1.2 x 10^{9} bacteria per ml.
‡ Mg ha^{-1} (5, 20, and 40 Mg ha^{-1} correspond to 0.5, 2.0, and 4.0 Mg 0.1 ha^{-1}).

Table 2. Effect of Amending Soil With Woodchips and Different Dilutions of EM 4 on Height of Cucumber.

Dilution†	Rate of Application‡			
	Control	Woodchips		
	0	5	20	40
	....	.... cm	....	....
Control (No EM)	123	125	162	90
1:2000	163	154	127	69
1:1000	162	144	113	64
1:500	162	152	101	71

† EM 4 dilutions were made from liquid stock culture that contained 1.2 x 10^{9} bacteria per ml.
‡ Mg ha^{-1}.

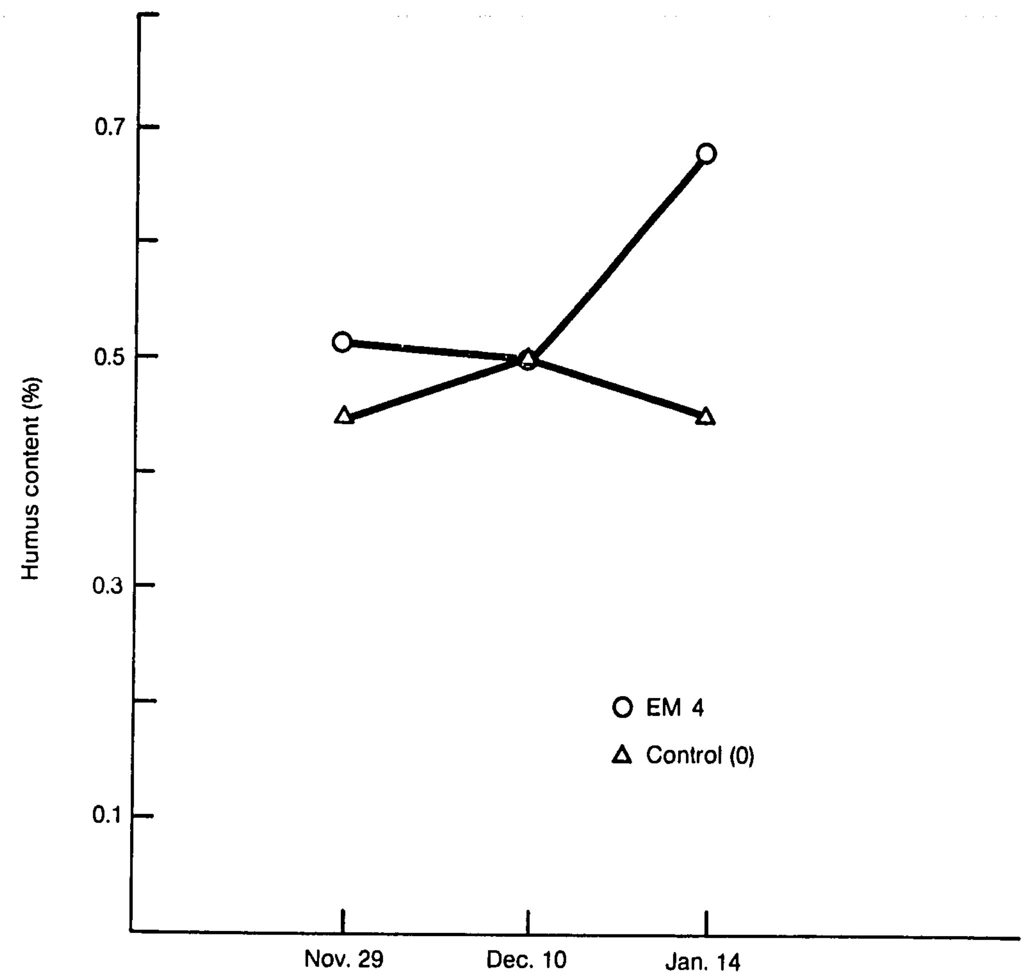

Figure 1. The Effect of Lactobacilli Inoculation on the Humus Content of Soil.

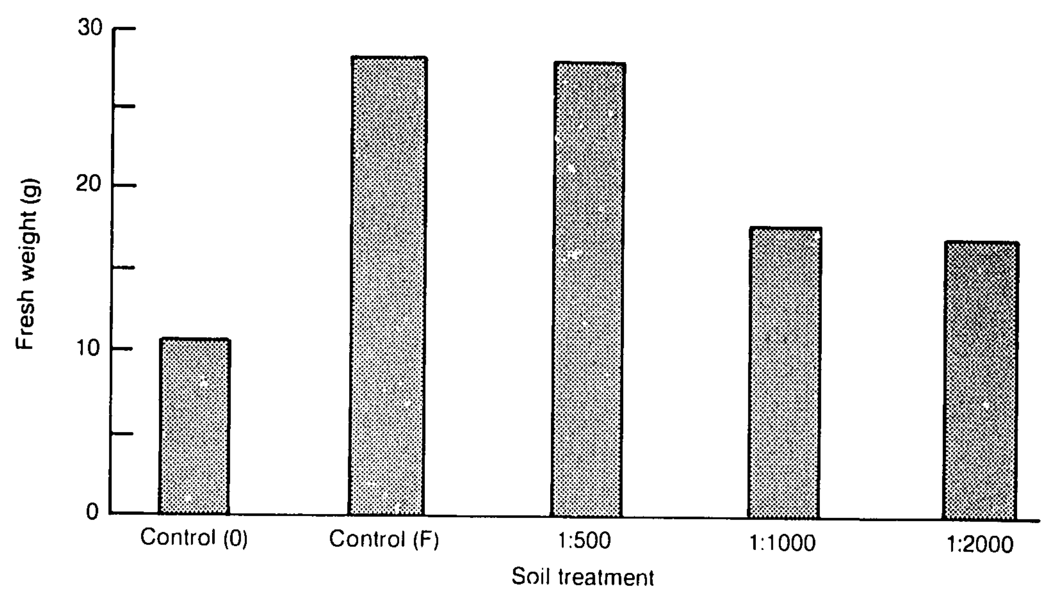

Figure 2. The Effect of Lactobacilli on the Fresh Weight Yield of Mustard Tops.

Table 3. Effect of an Organic Amendment and Different Dilutions of EM 4 on Microbial Populations in Soil Planted to Mustard†.

Treatment‡	Lactobacilli	Fungi	Aerobic Bacteria	Actinomycetes
	10^2 g^{-1}	*10^4 g^{-1}*	*10^5 g^{-1}*	*10^5 g^{-1}*
Control (Unamended)	1.38	1.31	1.45	0.0
Control (Amended)	0.512	7.74	5.03	2.62
1:2000	1.85	2.72	5.70	0.278
1:1000	1.51	2.12	11.8	7.02
1:500	2.07	2.44	6.09	0.976

† Microbial counts were made at time of harvest and are expressed as numbers per gram of dry soil.
‡ EM 4 dilutions were made from liquid stock culture that contained 1.2 x 10^9 bacteria per ml. The organic amendment, green chopped rose grass, was mixed with all pots, except the unamended control, at a rate of 40 Mg ha^{-1} (4.0 Mg 0.1 ha^{-1}).

There were no differences in the chemical analysis of soils among the various treatments. However, the numbers of microorganisms increased significantly in soil that was inoculated with EM 4 (Table 3). An exception to this was for actinomycetes which were lower in number for the 1:500 and 1:2000 EM 4 dilutions compared with the amended (and uninoculated) control.

Experiment 2b

Yield of radish tops (Figure 3) and radish roots (Figure 4) from application of lactobacilli to soil, at all three dilutions, was significantly greater than the unamended or amended controls. Again, there was little difference in soil chemical analyses due to treatments. Soil microbial populations were higher in the amended control than the unamended control (Table 4). Actinomycete populations were higher from application of lactobacilli compared with the amended control; however, the numbers of aerobic bacteria were somewhat lower than for the amended control. Fungal populations were highest after soil inoculation with lactobacilli at a dilution of 1:2000, while lactobacilli bacteria were highest at a dilution of 1:500.

Discussion

In the first experiment, the incorporation of woodchips in soil resulted in poor initial growth of cucumber, possibly because of immobilization of inorganic nitrogen. The results indicate, however, that EM 4 can be used successfully in combination with woodchips as an organic amendment by accelerating their rate of decomposition in soil. This is evidenced by the fact that the soil humus content from woodchips was significantly higher at the end of the experiment due to inoculation with EM 4. In most cases, the inoculation of unamended soil with EM 4 resulted in better growth of cucumber compared with soil amended with woodchips. The enhanced growth due to EM 4 may be related to the utilization of plant root exudates (Hale et al., 1978), and the solubilization and mineralization of certain soil nutrients to plant available forms.

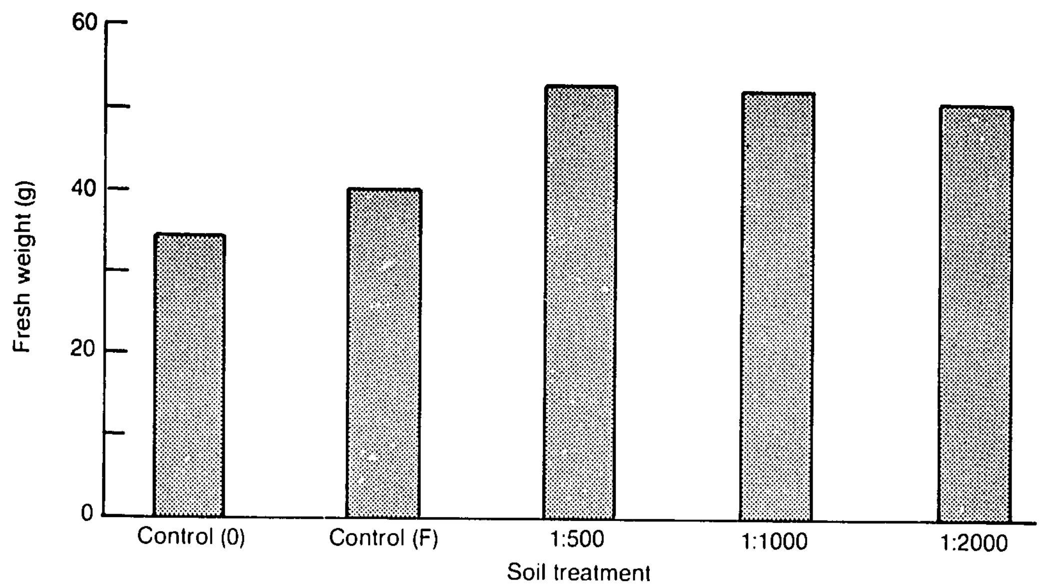

Figure 3. The Effect of Lactobacilli on the Fresh Weight Yield of Radish Tops.

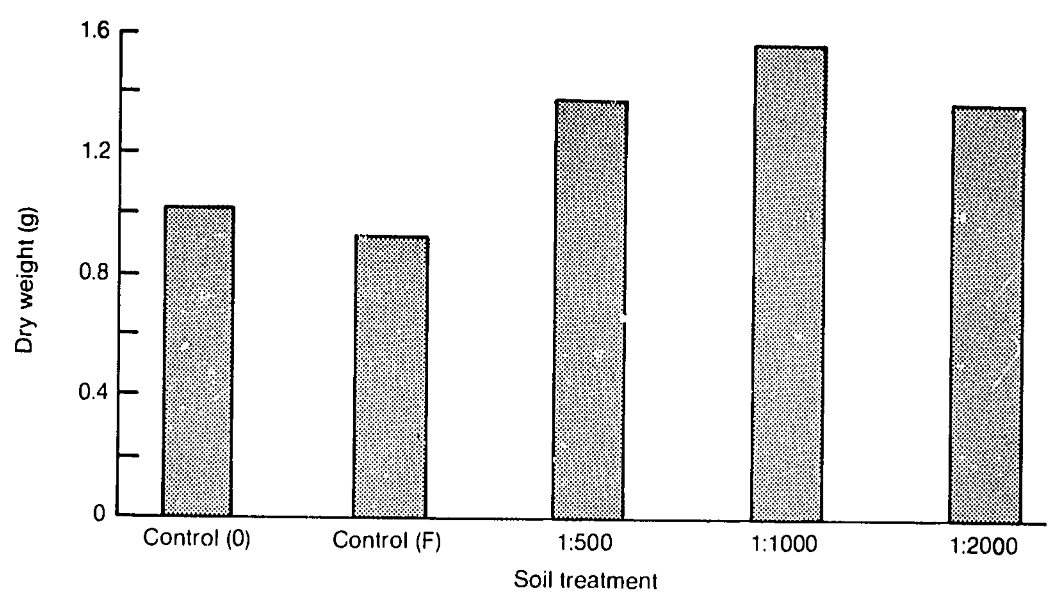

Figure 4. The Effect of Lactobacilli on the Dry Weight Yield of Radish Roots.

In the second experiment, results from the initial cropping were not conclusive. However in the second cropping, radish yields were higher from inoculation of soil with lactobacilli compared with the uninoculated controls. The higher root dry weight of radish shows the effective influence of lactobacilli on plant growth. A preliminary observation is that a more concentrated application of lactobacilli should probably be made during the initial growth period to achieve best results. Thereafter, the lactobacilli concentration can be reduced with time.

Table 4. Effect of an Organic Amendment and Different Dilutions of EM 4 on Microbial Populations in Soil Planted to Radish.†

Treatment‡	Lactobacilli	Fungi	Aerobic Bacteria	Actinomycetes
	10^{2} g^{-1}	*10^{4} g^{-1}*	*10^{5} g^{-1}*	*10^{5} g^{-1}*
Control (Unamended)	0.274	0.549	3.50	4.73
Control (Amended)	0.816	1.92	7.38	8.34
1:2000	0.676	2.58	5.34	10.7
1:1000	1.45	1.77	5.84	9.02
1:500	2.04	1.96	4.39	9.97

† Microbial counts were made at time of harvest and are expressed as numbers per gram of dry soil.

‡ EM 4 dilutions were made from liquid stock culture that contained 1.2 x 10^{9} bacteria per ml. The organic amendment, green chopped wild marigold, was mixed with all pots, except the unamended control, at a rate of 20 Mg ha^{-1} (2.0 Mg 0.1 ha^{-1}).

No significant differences were noted in the chemical analyses of the soil, including the humus content. A possible explanation for this may be that a pure culture of lactobacilli was utilized rather than a mixed culture. The lactobacilli are known to have a rather complex nutrient requirement and may require the presence of other compatible microorganisms to be most effective.

Humus formulation in soil is generally attributed to microorganisms other than the fermentative bacteria such as lactobacilli. Lactic acid bacteria do not readily decompose such complex materials as lignin and cellulose (Okada, 1988). Thus, it is likely that the application of EM 4 has an indirect effect on humus formation by modifying the soil microbiological equilibrium. Additional studies are needed to verify this possibility.

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Effective Microorganisms in Nature Farming: Weeding Effect of EM 4 in Paddy Fields

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ABSTRACT. The control of weeds in paddy rice has remained an unresolved problem in nature farming until now. Effective microorganisms (EM) have shown promise as a solution by accelerating the germination of weeds. Experiments were conducted to determine the best timing, frequency, and rate of application of EM 4 for controlling weeds in paddy rice. EM 4 reduced the amount and species of weeds. EM 4 was more active in a wet field, and its application at spring plowing and at puddling and leveling was sufficient to control annual weeds. Additional research is needed to determine the effect of EM 4 on perennial weeds.

Introduction

Although more than 50 years have passed since Kyusei Nature Farming was first advocated in Japan in 1936, the farming method still has three types of problems: the supply of adequate plant nutrients, the prevention of disease and insect infestation, and the control of weeds. The problem of weeds in growing or standing paddy rice was the main obstacle in extending the nature farming concept and methodology.

Various experiments and trials have been conducted to solve this problem. Some of these are deep water cultivation, crop rotations, the interrow hand weeding machine, the intrarow and interrow motorized weeding machine, and 2 to 3 puddlings and levelings. None of these, however, has been entirely satisfactory in solving the problem.

Effective microorganisms (EM) were introduced to nature farming during 1985, and have shown good prospects for solving the weed problem. Accelerated germination due to EM 4, in conjunction with the usual weeding method of 2 to 3 puddlings and levelings, have shown promise as a solution to the weed problem in paddy rice cultivation. Additional research is expected to establish this method as a highly acceptable means of weeding for paddy rice cultivation.

Kyusei Nature Farming is a farming method which uses no chemical fertilizers or pesticides. It emphasizes the use of natural systems to provide adequate nutrients for plant growth, and to enhance the health and protection of plants.

Materials and Methods

Field experiments were conducted to determine the effect of EM 4 in accelerating the germination of weed seeds in paddy rice cultivation, and the feasibility of using EM 4, in combination with puddling and leveling operations, as an improved weeding practice.

The sequence of cultivation practices and the results of the experiments are shown in Tables 1 and 2. The tables provide information on two comparative experiments and two practical experiments.

The difference in cultivation practices between the comparative experiments was because the time, rate, and frequency of EM 4 application, and the frequency of puddling and leveling were not firmly established when these studies were conducted. Furthermore, in the practical experiments no reference field was established and the simplest method for preventing weeds was used.

Composition and Function of EM 4

EM 4 is mainly composed of *Lactobacillus spp.*, with smaller numbers of photosynthetic bacteria, ray fungi, and yeasts.

Table 1. The Effect of Application Procedure of EM4 on Rice Growth and Weeds in Paddy Fields with Two Puddlings and Levelings: Comparative Experiments.

Grower		COMPARATIVE EXPERIMENT 1: H. Baba		COMPARATIVE EXPERIMENT 2: T. Tanabe	
Experiment lot		EM 4 applied	EM 4 not applied	EM 4 applied	EM 4 not oapplied
Variety		Koshihikari		Nihonbare	
Cultivation area		10 a	1 a	10 a	3 a
Fall plowing		Twice	Once	Once	Once
Spring plowing		Twice	Twice	Once	Once
Spray of EM 4 Saturated solution (1 ℓ /10a)	1st	Late Oct		Apr 29	
	2nd	Early Feb		May 7	
	3rd	Early Mar			
Puddling and leveling	1st	Apr 17	Mar 20	May 2	May 2
	2nd	Apr 27	Apr 13	May 7	May 7
	3rd	May 4	Apr 24		
Puddling interval		15 days	33 days	4 days	4 days
Rice planting		May 6	May 3	May 10	May 9
Weeding	1st	Late May (machine)	May 15 (machine)	May 25 (machine)	May 25 (machine)
	2nd	Mid Jun (machine)	May 25 (hand)	May 30 (hand) Jun 13 (machine) Jun 20 (hand)	Jun 13 (machine)
	3rd	Preharvest picking	Jun 10 (hand)		Jul 6 (hand)
Result	Weeding hours	Approx. 9 hrs/10a	Approx. 30 hrs/10a	Approx 12 hrs/10a	Approx 30 hrs/10a
	Weed growth †	1	4	2	4
Reference	Yield	433 kg/10a	290 kg/10a	554 kg/10a	377 kg/10a
	EM 2 and EM 3	Used	Not used	Used	Not used
	Weeding in previous year	Herbicides were used		Machine weeding: twice Hand weeding: twice	
	Location	Shiga Prefecture, JAPAN		Shiga Prefecture, JAPAN	

† Weed growth: 4 (very much), 3 (much), 2 (a little), 1 (very little), 0 (none).

Table 2. The Effect of Application Procedure of EM4 on Rice Growth and Weeds in Paddy Fields with Two Puddlings and Levelings: Practical Experiments.

Grower / Experiment lot		PRACTICAL EXPERIMENT 1 K. Nakazawa	PRACTICAL EXPERIMENT 2 R. Yamazaki
Variety		Nihonbare	Nihonbare
Cultivation area		6 a	7 a
Fall plowing		None	Once
Spring plowing		Once	Twice
Spray of EM 4 Saturated solution (1 ℓ /10a)	1st	Jun 13	Dec 14
	2nd		Mar 9
	3rd		Jun 10
Puddling and leveling	1st	Jun 13	Jun 10
	2nd	Jun 19	Jun 17
	3rd		
Puddling interval		5 days	6 days
Rice planting		Jun 20	Jun 20
Weeding	1st		
	2nd		
	3rd		
Result	Weeding hours	0 hr/10a	0 hr/10a
	Weed growth †	0	0
Reference	Yield	568 kg/10a	495 kg/10a
	EM 2 and EM 3	Used	Used
	Weeding in previous year	Machine: twice Hand: once	Herbicides were used
	Location	Kyoto JAPAN	Nara Pref. JAPAN

† Weed growth: 4 (very much), 3 (much), 2 (a little), 1 (very little), 0 (none).

Lactobacilli in EM 4 are capable of fermenting the husks of seeds, and in so doing can accelerate seed germination. EM 4 also has strong germicidal properties, and can directly suppress soil borne plant pathogens, including *Fusarium spp.* and *Sclerotinia sclerotium.* In addition, if green grass is plowed into soil and EM 4 is applied, lactobacilli will ferment the grass without complete decomposition. This means that the problems which occur during the decomposition process in soil are avoided and, hence, green grass can be converted into a compost-like material which, in turn, can improve soil productivity and the growth and yield of crops.

Method of Spraying EM 4

At fall plowing and spring plowing (no water in the field), 1 liter of a liquid stock culture of EM 4 was diluted with water to 1:1000 and sprayed over the field with a powered sprayer. At puddling and leveling (water in the field), 1 liter of a liquid stock culture of EM 4 was diluted with water to 1:50 to 1:10 and sprayed evenly over the field with a sprinkling can.

Results

In both the comparative experiments, the time required for weeding was shorter for the lot treated with EM 4 than for the untreated controls. Visual inspection of the fields clearly showed that the application of EM 4 reduced both the amount and species of weeds.

In the practical experiments, the weeding effect of EM 4 was more noticeable than for the comparative experiments. The time required for weeding was zero in both experiments. Visual inspection of the fields showed almost no weeds in the fields. Additional details are reported in the tables.

Discussion

Number of EM 4 Applications

Practical experiment 1 showed excellent results with the simplest procedure. In practical experiment 2, EM 4 was sprayed on the field a total of three times, once each at fall plowing, spring plowing, and puddling and leveling. It was sprayed only once at puddling and leveling in practical experiment 1, resulting in the same weeding time of zero hours. A conclusion here is that the spraying of EM 4 at fall plowing is unnecessary.

Water in the Field

It is inferred from the results of comparative experiment 1 that microorganisms become less active if they are sprayed when there is no water in the field (fall and spring plowing). This is supported by results from another practical experiment that concluded the amount of weeds in a wet field was reduced to one-half by spraying EM 4 only once at fall plowing.

Temperature and Puddling Interval

Since rice was planted late in the season in the practical experiments, the water temperature in the field was higher than that in the comparative experiments. Therefore, it can be assumed that weed seeds germinated fully in the practical experiments, although the interval of rough puddling and finished puddling was short (5 or 6 days) because the germination of weed seeds is faster at higher temperatures.

However, in comparative experiment 1, the germination of weed seeds was incomplete in the EM 4 treated lot because water temperature was low, although the puddling interval was 15 days.

The puddling interval in the EM 4 treated lot in comparative experiment 2 was only 4 days. If the interval was longer, more seeds could have germinated and weeding would have been more effective.

Among all the experiments, practical experiment 1 was the simplest and most effective method of weeding. However, the puddling interval needs to be longer in regions where rice is planted earlier in the season, and in cooler regions where early temperatures are low. Therefore, the most suitable and effective procedure of EM 4 application for each region will depend on specific climatic and agroecological conditions.

Future Research

The results of these experiments indicate that EM 4 can effectively control certain weeds in paddy rice cultivation. However, the weeds in these experiments were mainly annual weeds such as barnyard grass and, thus, it is not clear whether these same procedures would also be effective against perennial weeds. Therefore, weeding methods to control perennial weeds will be evaluated in future experiments.

Changes in the Soil Microflora Induced by Effective Microorganisms

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ABSTRACT. The beneficial effects of effective microorganisms (EM) on plant growth, yield, and quality have been consistently demonstrated. However, there are still questions about which EM cultures, or combinations thereof, are most effective for alleviating certain chemical, physical, and microbiological problems in soils. In the study reported here, EM cultures increased the number of Enterobacter spp. and starch digesting bacteria in soil. A combination of EM 2.3.4 markedly suppressed the number of Verticillium, Thielaviopsis, and Fusarium fungal species that are destructive soil borne plant pathogens. Some of the EM cultures significantly increased the population of Trichoderma (EM 2, EM 3, EM 2.3) and Penicillium (EM 3, EM 2.3, EM 2.3.4) species that are known to suppress plant pathogenic fungi in soils. Soil physical properties, including cultivation depth and porosity, were generally improved by EM treatment.

EM 3, EM 4, and EM 3.4 effectively suppressed nematode damage on tomato plants. With the exception of EM 2, all other EM cultures appeared to either suppress insect damage or heal fruit injuries on tomato caused by insects. Tomato yields obtained with EM 3, EM 4, and EM 2.3 were comparable to, though less than, the fertilized control. However, the amount of marketable fruit was considerably greater for these EM treatments than for the fertilized plot.

Introduction

Soil microorganisms can have both positive and negative effects on plant growth. They can facilitate nutrient absorption by plants (Bowen and Rovira, 1966); promote plant growth or stimulate seedling development by producing hormone-like substances (Rubenchick, 1963; Mishustin 1970; Brown, 1974); suppress and control plant pathogens and diseases through various antagonistic activities (Marois et al., 1981); or adversely affect plant growth through their pathogenic behavior (Elad, 1985).

A principal goal of nature farming is to produce abundant and healthy crops without using chemical fertilizers and pesticides, and without interrupting the natural ecosystem. Higa (1986; 1988) investigated the effect of effective microorganisms (EM) on different horticultural crops at the University of The Ryukyus. The beneficial effects of EM have been demonstrated when applied to horticultural crops. Questions still remain about which combination of EM cultures changes specific problem soils into healthier and more productive soils, that is, disease-suppressive soils, synthetic soils or zymogenic soils. We need to know which combinations of EM can favorably interact with soil microbial communities and promote beneficial relationships between biotic and abiotic factors which enhance the health and growth of plants.

The purpose of this study was to investigate the effects of EM on the soil microflora, the effects of EM on soil physical and chemical properties, and how the nature farming concept can be successfully applied to modern agriculture.

Materials and Methods

EM 2, EM 3, and EM 4 were obtained from the Horticulture Laboratory, Department of Agriculture, the University of The Ryukyus in Okinawa, Japan. The EM cultures were classified as follows (Higa (1988):

1) **EM 2.** EM 2 is a mixture of more than 10 genera and 80 species of coexisting microorganisms (photosynthetic bacteria, ray fungus, yeast, molds, etc.) that were cultured in a liquid medium controlled at pH 7.0 and stored at pH 8.5. The number of microorganisms in saturated culture solution was 10^9 g^{-1}.
2) **EM 3.** EM 3 consists of 95% photosynthetic bacteria that were cultured in a liquid medium and stored at pH 8.5. The number of microorganisms was 10^9 g^{-1}.

3) **EM 4.** EM 4 consists of 90% *Lactobacillus spp.* and microorganisms producing lactic acid, that were cultured in a liquid medium at pH 4.5. The number of microorganisms in the solution was 10^9 g^{-1}.

The experiments were initiated October 23, 1988 at the University of The Ryukyus in Okinawa. Soil was classified as gray upland soil with a pH of 8.3 and had not been cultivated for many years.

To determine the effect of EM on crop production, spinach (var. Radikaru) and tomato (var. Oogata Fukuju) were used.

Prior to planting, the soil was mixed with 1 kg of dry grass m^{-2} which contained 1% N, and with enough oil meal to supply 3 g N m^{-2}. Soil physical and chemical properties and microbial analysis were determined on soil samples that were taken after the tomato crop was harvested.

Plots were established as a randomized complete block with three replications. Treatments included EM 2, EM 3, EM 4, EM 2.3, EM 2.4, EM 3.4, EM 2.3.4, an unfertilized control (O) without EM, and a fertilized control (OF) without EM. Sufficient levels of N, P, and K were applied to the fertilized control to sustain optimum plant growth. EM cultures were diluted to concentrations of 0.1% from liquid stock media and watered into the soil at two-week intervals.

Total microorganisms in the soil were estimated by the plate count method. Bacteria and actinomycete populations were counted on egg albumin agar (Tadao, 1984). Total fungi were counted on rose bengal agar (Martin, 1950). *Azotobacter* were isolated on nitrogen-free mannitol broth agar (Harrigan and Margaret, 1966). *Clostridia* were isolated on media described by Sheldon (1970). *Lactobacillus spp.* were counted on Rogosa agar (Harrigan and Margaret, 1966). *Enterobacter* was counted on MacConkey agar (Harrigan and Margaret, 1966). Starch digesting bacteria were counted using the method of Sheldon (1970). *Agrobacterium, Erwinia, Pseudomonas,* and *Xanthomonas spp.* were counted on D1, D3, D4, and D5 selective media, respectively (Kado and Heskett, 1970). *Fusarium* was counted on Komada's medium (Tadao, 1984); *Verticillium* on alcohol agar medium (Mathew and Chester, 1959); and *Thielaviopsis* on RBM2 medium (Tsao, 1964).

Soil bulk density and porosity were determined according to methods described by Henry (1984), using 2 and 4 cm diameter cores from each plot taken to a depth of 10 cm. Soil porosity was calculated from the ratio of pore space and soil volume. Soil aggregation was determined by the pipette method described by Martin and Waksman (1940). Soil phosphorus content was determined by the method of Hormers and Parker (1961).

Results

Change in Soil Microflora

In most cases, the numbers of bacteria, fungi, and actinomycetes increased after the soil was treated with EM cultures, although the numbers of actinomycetes measured in treatments EM 2.3 and EM 2.4 were lower than the unfertilized control (Table 1). It was interesting that the lowest number of actinomycetes occurred when the soil was treated with only fertilizer (OF).

Generic anaylsis of the bacterial flora in the soil due to EM treatment is shown in Table 2. In most cases EM cultures markedly increased the number of *Enterobacter spp.* and starch digesting bacteria over that of the unfertilized control (O), but had little effect on enhancing the numbers of *Lactobacillus spp.* The highest numbers of *Azotobacter* and *Clostridium* species were attained with the fertilized control (OF), while the lowest number of each occurred with the unfertilized control (O). The highest number of *Xanthomonas* and *Erwinia* species were found in the fertilized control (OF), the highest number of

Table 1. Effect of EM Cultures on Numbers of Soil Microorganisms.†

Treatment‡	Bacteria	Fungi	Actinomycetes
	$X10^5$	*$X10^3$*	*$X10^4$*
O	47.8	9.42	17.9
OF	59.4	23.1	8.38
EM 2	69.3	39.1	17.8
EM 3	79.8	36.9	29.5
EM 4	147	35.5	29.6
EM 2.3	136	34.7	11.4
EM 2.4	112	39.7	11.6
EM 3.4	105	11.8	39.2
EM 2.3.4	118	14.0	20.2

†Microorganisms per gram of soil (dry weight basis) counted prior to planting tomatoes.
‡Unfertilized control without EM (O). Fertilized control without EM (OF)

Agrobacterium species from treatment with EM 2.3.4, and the highest number of *Pseudomonas* from EM 2.3.

The number of fungal species after EM treatment of this soil are shown in Table 3. The highest number of *Trichoderma* species was found after treatment with EM 2.3 and the highest number of *Penicillium* with EM 3. However, the lowest number of specimens in these genera resulted from the fertilizer treatment (OF). The highest number of *Verticillium* species was observed in the fertilized control (OF) and with EM 4. But, the combination of EM 2.3.4 appeared to suppress the numbers of this soil borne plant pathogen. Treatment with EM 2, EM 3, and EM 2.3.4 appeared to suppress *Thielaviopsis*, a potential plant pathogen. The highest number of *Fusarium* species resulted from treatment with the fertilized control (OF), while the combination of EM 2.3.4 markedly suppressed the numbers of this particularly destructive plant pathogen.

Change in Soil Physical and Chemical Properties

Soil physical properties were determined one year after treatment with the EM cultures and are shown in Table 4. Cultivation depth and porosity were significantly higher with most EM treatments than with the controls, (O) and (OF). Soil hardness was significantly higher for the unfertilized control, although it was also high for several of the EM treatments. There was little difference in soil bulk density among all treatments.

Soil aggregation was higher for all EM treatments than either the unfertilized control (O) or fertilized control (OF). Soil aggregation actually decreased from the application of fertilizer to this soil.

Table 2. Effect of EM Cultures on Generic Composition and Populations of Bacteria in Soil.†

Treatment‡	*Entero-bacteria*	Starch Digesting	*Lacto-bacillus*	*Azoto-bacter*	*Clostri-dium*	*Xantho-monas*	*Erwina*	*Agro-bacterium*	*Pseudo-monas*
	$X10^3$	$X10^4$	$X10^2$	$X10^2$	$X10^2$	$X10^5$	$X10^3$	$X10^4$	$X10^3$
O	239	170	20	5	17	100	404	103	39
OF	224	300	20	700	282	133	800	73	135
EM 2	673	400	28	98	61	41	209	106	422
EM 3	266	225	18	72	120	22	228	68	52
EM 4	273	103	28	700	50	29	164	57	242
EM 2.3	724	100	23	100	154	23	431	114	1090
EM 2.4	385	150	27	500	191	20	500	64	392
EM 3.4	132	219	23	500	40	25	352	41	166
EM 2.3.4	415	175	20	500	25	30	382	189	134

†Bacteria per gram of soil (dry weight basis) counted at the second planting of tomatoes.
‡Unfertilized control without EM (O). Fertilized control without EM (OF).

Table 3. Effect of EM Cultures on Fungal Populations in Soil.†

Treatment‡	*Trichoderma*	*Penicillium*	*Verticillium*	*Thielaviopsis*	*Fusarium*
	$X10^2$	$X10^3$	$X10^3$	$X10^3$	$X10^2$
O	2.77	3.96	32.9	25.0	228
OF	0.77	1.15	38.7	18.8	465
EM 2	9.25	1.61	28.6	12.9	110
EM 3	5.87	8.61	25.8	10.9	277
EM 4	2.73	3.50	38.6	21.0	105
EM 2.3	20.4	5.09	24.7	18.4	182
EM 2.4	1.18	3.14	22.0	20.8	143
EM 3.4	2.75	1.57	22.8	22.8	154
EM 2.3.4	0.78	5.10	16.1	16.1	73

†Fungi per gram of soil (dry weight basis) counted at the second planting of tomatoes.
‡Unfertilized control without EM (O). Fertilized control without EM (OF).

Table 4. Effect of EM Cultures on Soil Physical Properties.

Treatment†	Cultivation Depth	Soil Hardness	Porosity	Bulk Density	Aggregation
	cm	*kg cm*$^{-2}$	%	*g cm*$^{-3}$	%
O	23.7c‡	2.75a	52.9c	1.17ab	70.1
OF	23.9c	1.87bcd	52.7c	1.17a	67.4
EM 2	28.5b	1.63e	53.7b	1.17a	71.7
EM 3	28.3b	1.74e	53.7b	1.16a	73.2
EM 4	32.1b	1.58e	58.7a	1.08b	71.7
EM 2.3	27.0b	1.91bcd	56.8ab	1.16a	71.4
EM 2.4	29.9b	2.40ab	55.7ab	1.11ab	72.0
EM 3.4	30.1b	2.20abc	54.8ab	1.13ab	71.9
EM 2.3.4	32.3a	1.77de	52.2ab	1.16a	71.0

†Unfertilized control without EM (O). Fertilized control without EM (OF).
‡Means in columns followed by the same letter do not differ significantly at P 0.05.

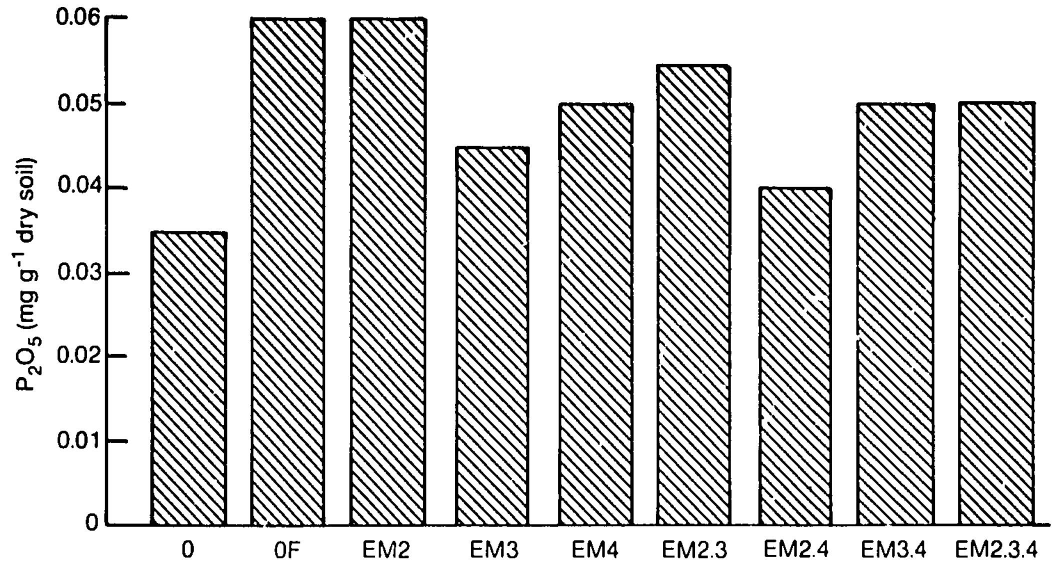

Figure 1. The Effect of EM Cultures on Soil P_2O_5 Content.

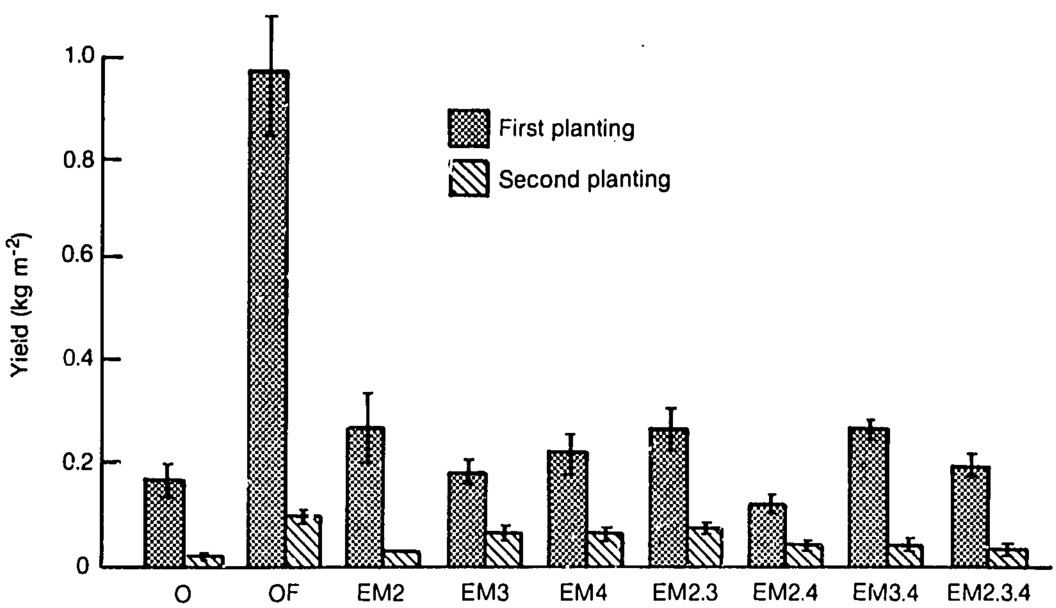

Figure 2. The Effect of EM Cultures on the Yield on Tomatoes.

There was little difference in the effect of EM treatment, or the controls, on such parameters as soil pH and humus content, or on nutrients such as nitrate, ammonium, and potassium. The most dramatic effect of EM treatments on soil nutrient composition was the increased level of inorganic (plant available) phosphorus which was higher than the unfertilized control (O) in all cases (Figure 1).

Tomato and Spinach Production

Tomato yields for the first crop showed no significant difference between the EM treatments and the unfertilized control (O). However, yields were significantly higher with the fertilized control (OF) than the EM treatments (Figure 2 and Table 5). The number of nematode galls on tomato plants grown in the control plots, both fertilized and unfertilized, and with EM 2 were higher than for the other treatments. EM 3, EM 4, and EM 3.4 were particularly effective in suppressing nematode damage.

Table 5. Effect of EM Cultures on Yield and Quality of A Tomato Crop.

Treatment†	Plant Height	Root Fresh Weight	*Fusarium*‡	Galls/ Plant	Gall Weight	Yield
	cm	*g*	*X10*^{2}	*No.*	*g*	*% of control*
O	70.0	13.4	228	83.0	1.20	100
OF	161	37.9	465	13.7	2.69	598
EM 2	84.9	23.9	100	14.6	3.12	162
EM 3	87.2	21.7	277	7.4	0.72	108
EM 4	90.0	19.2	105	5.0	0.87	133
EM 2.3	97.1	24.5	183	10.0	2.57	164
EM 2.4	69.2	18.2	143	10.7	2.50	70.1
EM 3.4	81.0	19.8	154	3.9	0.73	162
EM 2.3.4	79.8	17.3	73	11.2	2.05	117

†Unfertilized control without EM (O). Fertilized control without EM (OF).
‡Fusarium fungi per gram of soil (dry weight basis).

Table 6 shows the indirect effect of EM treatments on covering tomato fruit injuries caused by green june bug. The percentage of fruit damaged by the insect on control plots and with EM 2 were higher than for the other treatments. The other EM cultures appeared to either suppress insect damage or heal fruit injuries caused by the insects. The lowest fruit yield was on the unfertilized control (O) plots, and the highest yield was from the fertilized control (OF). Among the EM treatments, the highest yields were obtained with EM 3, EM 4, and EM 2.3. While these yields were somewhat less than the fertilized control, the number of marketable tomatoes was considerably higher for these EM treatments than for the fertilized plots.

The effect of continuous cropping and EM treatments on spinach production is reported in Figure 3. Continuous cropping tends to decrease spinach production. The highest production was achieved on the fertilized control (OF) and the lowest on the unfertilized control (O).

Discussion

The lowest number of actinomycetes occurred in soil treated with fertilizer (OF) suggesting that these microorganisms may somehow have been suppressed, either directly or indirectly, by the fertilizer components. Beliaev (1958) found that continuous application of ammonium fertilizer without lime can suppress the actinomycetes since the ammonium is oxidized to nitric acid by microbial action. The resultant decrease in soil pH can cause unfavorable growth conditions.

Table 6. Indirect Effect of EM Cultures on Covering Fruit Injuries by Insects.

Treatment†	Production	Marketable Fruit	Fruit Damage	Fruit Damage
	g m⁻²	*No.*	*No.*	*%*
O	110	15	69	82.1
OF	875	55	114	67.5
EM 2	212	12	57	82.6
EM 3	616	66	27	29.0
EM 4	558	69	30	30.3
EM 2.3	697	60	30	33.3
EM 2.4	366	42	12	22.2
EM 3.4	366	30	45	60.0
EM 2.3.4	312	30	14	31.8

†Unfertilized control without EM (O). Fertilized control without EM (OF).

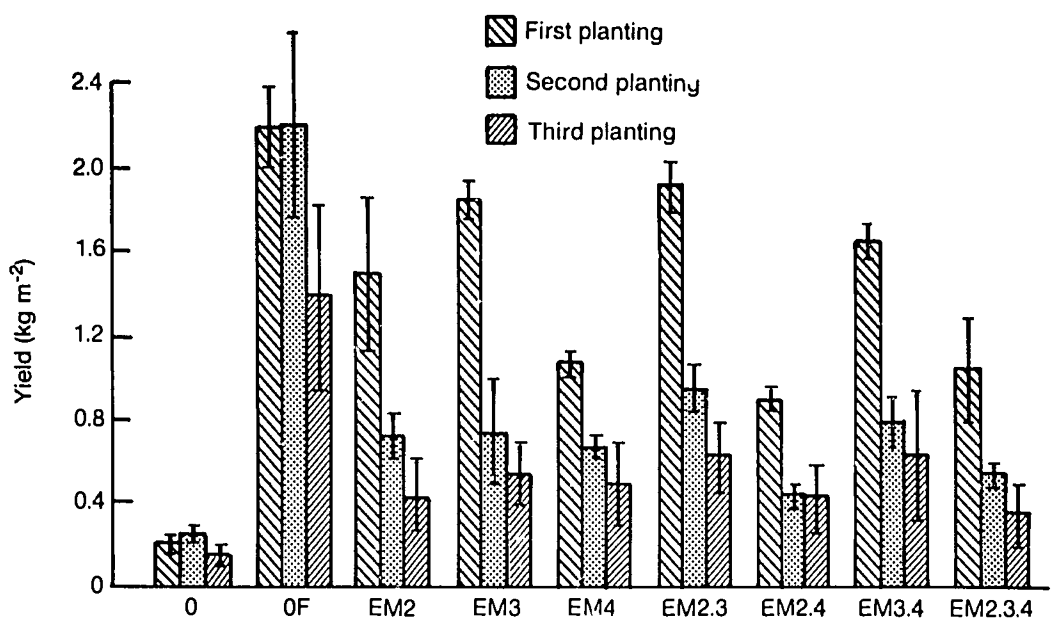

Figure 3. The Effect of EM Cultures on the Yield of Spinach.

The generic analysis of the bacterial flora (Table 2) showed that fermentative bacteria such as *Enterobacter*, starch digesting bacteria, *Azotobacter*, and *Clostridia*, are present in soil treated with EM and the fertilized control (OF), but to a lesser extent in the unfertilized control (O). This may have been due to the effect of some specific nutrient requirement for the growth of fermentative bacteria. Gyllenberg (1956) reported seasonal variations in which the relative abundance of Aa grouping bacteria increased, with a corresponding decrease in the abundance of Ba grouping bacteria. It remains unexplained whether the increase in the relative abundance of the Aa grouping bacteria was accompanied by the accumulation of specific nutrients such as amino acids.

There is not a clear relationship between EM treatments and the number of soil disease bacteria, e.g., *Xanthomonas*, *Erwinia*, *Agrobacterium*, and *Pseudomonas*, as shown in Table 2. But in the preliminary experiment it appeared that treatment with EM 4 is associated with a rather low population of disease bacteria.

The effect of EM on fungal populations in soil (Table 3), indicated that soil treated with only fertilizer had low numbers of *Penicillium* and *Trichoderma*. These beneficial fungi can play an important role in inhibiting or suppressing soil-borne microbial plant pathogens through their antagonistic activities. Large numbers of fungal disease pathogens were found in both of the control treatments.

The effect of EM on soil physical properties suggests that EM can induce plant roots to penetrate soil more effectively. Soil treated with EM becomes more friable and porous, less compact, and promotes deeper cultivation. Microorganisms, particularly fungi, can bind soil particles into more stable aggregates Bacteria can synthesize cementing agents in the form of gums and polysaccharides that also help to promote good aggregation. Lynch (1981) found that *Azotobacter chroococcum*, *Lipomyces starkeyi*, and *Pseudomonas spp.* can promote the stabilization of soil aggregates.

Insoluble soil phosphorus compounds (both organic and inorganic) are largely unavailable to plants, however, many microorganisms can solubilize these compounds and make them available for uptake. Martin (1961) found that one-tenth to one-half of the bacterial isolates he tested were capable of solubilizing calcium phosphate. Fungal species of the genera *Pseudomonas*, *Mycobacter*, *Micrococcus*, *Flavobacterium*, *Penicillium*, *Sclerotium*, *Aspergillus*, and others are also known to solubilize insoluble phosphates to plant-available forms.

EM treatment has an indirect effect on covering or healing tomato fruit injuries caused by green june bug (figeater). Fruit damage was greatest for the controls and for the EM 2 treatment. However, fruit damage was considerably less with the other EM cultures compared with the controls. These results are probably soil specific. Soils that do not have a good fermentation potential can produce malodors and attract harmful insects that prefer to lay their eggs in that soil. Nevertheless, it is noteworthy that three of the EM treatments, EM 3, EM 4, and EM 2.3 produced yields that were comparable to, though less than, the fertilized control. These three EM cultures also produced a greater amount of marketable fruit than the fertilized control indicating a beneficial effect of EM on fruit quality. The actual role of EM in covering tomato fruit injuries needs further investigation to determine precisely what relationships and mechanisms are involved in this process.

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Section VI
Conclusions and Recommendations of the Working Groups

State of the Art of Kyusei Nature Farming

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Kyusei Nature Farming is the farming method which was first advocated by Mokichi Okada of Japan in 1935, based on his belief that "the world can be transformed into a paradise by eradicating disease, poverty, and conflict."

The following requirements, which are not seen in conventional farming methods, are imposed on Kyusei Nature Farming:

1) It must produce superior food for the advancement of human health.
2) It must be economically and spiritually beneficial to both farmers and consumers.
3) It must be sustainable, and be easily practiced by anybody.
4) It must conform to nature and maintain the environment.
5) It must produce enough food for the increasing population of the world.

As in many other natural farming systems, Kyusei Nature Farming does not advocate the use of synthetic chemicals which can harm the environment. Kyusei Nature Farming differs from other natural farming methods in that it uses the technology of effective microorganisms (EM), developed by Teruo Higa of Japan, to enhance plant growth, health, and yield, and to maintain a natural balance in the environment. EM is a transitional tool to help build up the soil.

Because the technology for the production of EM is complex, the International Nature Farming Research Center of Japan will supply to Thailand and other interested individuals/countries free samples of EM and adequate technical assistance to ensure proper usage. The use of EM is an emerging technology. In order to determine whether it would be economically viable, socially acceptable, and regionally suitable to use EM on an international level, statistically valid experiments must be conducted by the national and regional universities on experiment stations and in on-farm situations. These experiments would determine:

1) The soil and environmental/regional conditions that may limit or enhance the effectiveness of EM.
2) The potential impact of EM on yield, income, and the environment.
3) The long-term impact of EM on the microbiology of the soil.
4) The costs of EM as a commercial product.
5) The length of time required to establish a stable population of EM in the soil.
6) How the effectiveness, availability and cost of EM will affect a farmer's self-reliance.

Research Needs and Priorities

H.A.H. Sharifuddin and U.R. Sangakkara
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Introduction

The research needs and priorities will depend on the state of the art of natural farming in each specific country. For example, countries with advanced research and natural farming experience will certainly have needs and priorities different from those with less experience and research in natural farming. Nevertheless, prioritization is needed, though each country may choose where to begin depending on their own experiences and needs.

Three major categories of concern were:

1) Technological aspects,
2) Methodology, and
3) Implementation.

Technological Aspects

Technology is classified under short-term and long-term priorities. These classifications are based on the expected results from the research done.

Short-Term Priorities

Three factors were identified in short term research needs, and the priorities listed.

Soil Factors. Soil factors can be broadly divided into three areas: inputs, use of microbes, and site specific problems. The needs in each follow in order of priority:

1) *Inputs.* Research in this area should concentrate on the reduction and/or elimination of the use of organic fertilizer. This can be achieved through research on the use of organic matter, including green manure; the use of mine materials, e.g., rock phosphate, limestone, and gypsum; and the use of byproducts e.g., fly ash.
2) *Use of microbes.* Study on the efficient use of microbes to improve soil fertility and plant growth, including research on the use of effective microorganisms (EM). Much research is required in this new area since most researchers have only been exposed to the technological aspects of EM through this conference.
3) *Site specific problems.* These include soil amendments to improve physical properties of the soils, and other specific problems such as improving the quality of irrigation water.

Pest Factors. Research on pests (including insects, pathogens, and weeds) should emphasize the elimination and/or reduction of the use of chemicals. In this area, three aspects of research were identified, namely:

1) *Natural products.* The identification and use of plant extracts and inert materials.
2) *Biological control.* The identification and use of parasites and predators, and the possibility of using sterile male techniques.
3) *Crop and soil management.* Research on specific crop/soil management techniques to enhance production and reduce the need of using chemicals.

Animal Factors. The integration of an animal component (including fish) into the natural farming system should be considered as one of the key considerations for developing a self-sustainable and efficient system.

Long-Term Priorities

All research needs should have long-term objectives, including the areas listed in the short-term priorities. However, one area which cannot be considered in the short-term objectives is selection and breeding. In this area, the selection of suitable genetic material and breeding to obtain high-yielding and resistant varieties that are especially suited to natural farming should become a priority to plant breeders. A new program is urgently needed since the current breeding programs are mainly based on high-input technology.

Methodology

Three general methods of experimentation were of concern:

1) On-farm research,
2) Experiment station field studies, and
3) Glasshouse/laboratory studies.

The methodology adopted in any research program depends on the knowledge already available in the country or region with similar environments. Basic studies should precede research on a farmer's field. As an example, work on new technology such as the use of EM should start in the glasshouse and experiment station, and expand to farm research and extension programs after sufficient knowledge and confidence are obtained.

Implementation

The implementation of any research program has two fundamental aspects. It could be either a specific or a holistic approach. The group is unanimous in the opinion that if there are sufficient knowledge and techniques available, a holistic approach should be tried. If not, specific research should be conducted to solve specific problems, keeping in mind the final goal of the holistic approach and develop a package technology for natural farming.

Note: The report of this working committee did not touch on the actual methodologies of research, the time frame, and the financial aspects. This is due to the wide disparities in each of these areas between countries, and, as such, these three aspects could not be listed and prioritized.

The group also noted the need for information flow between researchers and the availability of literature/publications to speed up progress towards the goals.

Networking and Linkages

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Introduction

While some valuable work has been done for a number of years on alternative agriculture/natural farming, solid information on it and the impact on agricultural economies is not well-documented and disseminated in most countries. It is important for researchers, extension workers, educators, and farmers, as well as planners and administrators to be aware of newer practices and emerging techniques, so as to avoid duplication of effort and wasted motion and resources. It is also highly desirable to coordinate activities and plan collaborative efforts.

Therefore, the First International Conference on Kyusei Nature Farming recommends that suitable linkages be developed and networks set up at the national, regional, and international levels. Four main categories of concern were:

1) Levels of networking/linkages,
2) Participation at different levels,
3) Modes of operation, and
4) Financing.

Levels of Networking/Linkages

National Level

Establishment of a national level organization on natural farming/alternative agriculture is recommended by the working group. Efforts should be made to keep the national organization as broad-based as possible. Conditions differ from country to country and, hence, flexibility is needed. In developing countries, for instance, support from official agencies would be necessary. The assistance of nongovernmental and private, voluntary organizations would also be vital.

It would be desirable if information, in addition to Proceedings of this Conference, is supplied to all the participants, regarding:

1) Details of work done by the International Promotion Committee of Kyusei Nature Farming; and
2) Details of work done by similar groups in other countries where available.

Regional Level

Regions can be categorized according to broad similarities in agroclimatic conditions, commonality in problems and issues, and other relevant criteria. For example, Asia and the Pacific can be one region. Close cooperation of governmental and nongovernmental organizations from different regions should be solicited, e.g., from ESCAP, FAO Regional Offices, ASEAN, SAARC, etc.

International Level

This First International Conference on Natural Farming took place because of the efforts of the International Promotion Committee of Kyusei Nature Farming, Japan, and Khon Kaen University, Thailand. The Conference has been very successful, with plans to hold a second international meeting in 1991, again under the sponsorship of the International Promotion Committee of Kyusei Nature Farming, Japan.

After this significant initial thrust, it is important to continue this worthwhile activity. The structure of future conferences can be developed and fine-tuned as we go along. Of course, at the international level, the help of intergovernmental and private individuals would be highly desirable.

Participation at Different Levels

Researchers, extension workers, educators, farmers, and planner/administrators participate at different levels. The degree of participation by people in each group will differ from country to country depending upon interest, the level of sophistication in terms of knowledge and their assigned responsibilities, if any, and on the capacity (financial and otherwise) to take part in proposed deliberations at the various levels.

Modes of Operation

To achieve the aims of natural farming, a number of things will have to be done including:

1) Obtaining grants for research and other activities;

2) Imparting training in practical techniques and philosophy of natural farming;

3) Organizing conferences, seminars, workshops, etc.;

4) Publishing reports, periodicals, journals, newsletters, etc.; and

5) Public relations/lobbying.

Financing of Various Activities

The following sources should be tapped:

1) Government funds—such allocation of money would be imperative in most, if not all, developing countries;

2) International funding organizations—official agencies, e.g., UNDP, FAO, World Bank, Asian Development Bank, and nongovernmental organizations;

3) Private organizations, e.g., the International Promotion Committee of Kyusei Nature Farming;

4) Foundations, e.g., Winrock International of the United States; and

5) Charitable groups.

Section VII
Appendix

APNAN
Asia-Pacific Natural Agriculture Network

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Founding of APNAN

The Asia-Pacific Natural Agricultural Network (APNAN) was founded at the First International Nature Farming Conference that was held during October 17-21, 1989 at Khon Kaen, Thailand. A Steering Committee with members of 13 Asian and Pacific countries was established to provide scientific and administrative counsel to APNAN's president and coordinator.

Professor Teruo Higa, a distinguished agricultural scientist at the University of the Ryukyus, Okinawa, Japan and expert on natural farming systems was elected as the founding President of APNAN.

Purpose of APNAN

The purpose or goal of APNAN is to establish an international network of scientists in the Asia-Pacific Region that would promote research and education programs on natural farming practices and technologies.

Objectives of APNAN

The objectives of APNAN are to:

1) Avoid or largely exclude the use of synthetic agricultural chemicals, especially fertilizers and pesticides.
2) Enhance environmental quality and protection of the natural resource base.
3) Improve the productivity and profitability of small farmers and the long-term sustainability of their farming systems.
4) Optimize the use of on-farm resources and minimize the dependence of farmers on purchased inputs, especially fertilizers and pesticides.
5) Enhance the safety and nutritional quality of food.

Current Workplan

Currently the APNAN members are conducting research studies to evaluate the reported benefits of effective microorganisms as inoculants in natural farming systems. Specifically, they are studying the effect of these microbial inoculants on the decomposition of organic amendments in soils, nutrient release and cycling, soil properties, and crop growth and yield. While somewhat similar experiments are being conducted for comparative purposes, APNAN members are directing their research toward local agroecological conditions and the specific farming systems of their own countries.

Associated Agencies

The primary nongovernmental agency that supports APNAN is the International Nature Farming Research Center at Atami, Japan which advocates the principles of natural farming and self-reliance. Support of the U.S. Department of Agriculture is provided through the service of technical advisors to APNAN.

Forthcoming Activities

The Steering Committee meets every 12 to 18 months in one of the APNAN countries to report and evaluate research results, and priorities.

The Second International Nature Farming Conference will be held in Brazil during October 1991.

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Asia-Pacific Natural Agriculture Network
APNAN

We the Founding Members of the Asia-Pacific Natural Agriculture Network (APNAN) hereby commit ourselves, this 21st day of October, 1989, to actively engage in efforts that support the research, development, and implementation of natural agriculture techniques that:

1) Lead to the elimination of dependence on synthetic agricultural chemicals;
2) Are based on local agroecological conditions;
3) Assist small farmers to increase their income; and
4) Lead to self-reliance on the part of farmers in a sustainable agriculture system.

Dr. Chaitat Pairintra, Associate Professor, Department of Soil Science, Khon Kaen University, Thailand, was unanimously selected as the Coordinator of APNAN, and Dr. Tahir Hussain, Associate Professor, Department of Soil Science, University of Agriculture, Faisalabad, Pakistan, will serve as co-coordinator.

The headquarters of APNAN shall be at Bangkok, Thailand.
There shall be a Steering Committee to plan the activities of the network.

Initial members of the APNAN Steering Committee are as follows:

1) Dr. Teruo Higa, The College of Agriculture, Okinawa, Japan, President.
2) Dr. Chaitat Pairintra, Khon Kaen University, Khon Kaen, Thailand, Coordinator.
3) Dr. Tahir Hussain, University of Agriculture, Faisalabad, Pakistan, Co-coordinator.
4) Dr. Har Swarup Singh, Haryana Agricultural University, India.
5) Dr. R. Sangakkara, University of Peradeniya, Sri Lanka.
6) Dr. Shariffuddin, University Pertanian Malaysia, Malaysia.
7) Dr. Teodoro Mendoza, University of Philippines at Los Banos, Philippines.
8) Dr. Cho Cho Myint, Institute of Agriculture, Myanmar.
9) Mr. David Lung-Li Lin, Taiwan Natural Farming Research Center, Taipei, Taiwan.
10) Dr. M. S. Wigenasantana, Indonesia.
11) Dr. Kyung-Hee Lee, Korea.
12) Dr. Tawisuk Santawisuk, Khon Kaen University, Khon Kaen, Thailand, Technical Advisor.
13) Dr. James F. Parr, U.S. Department of Agriculture, USA, Technical Advisor.
14) Dr. Sharon B. Hornick, U.S. Department of Agriculture, USA, Technical Advisor.

APNAN shall hold a site visit, tour, and a planning meeting workshop every two years in a member country, as approved by the Steering Committee, to discuss the results from each country and to plan future strategies on natural farming.

The Sekai Kyusei Kyo, an NGO of Japan, shall be requested to finance APNAN activities.

The coordinator will write letters of information containing recommendations of the International Conference on Kyusei Nature Farming as well as an introduction of APNAN to the Federal Ministers of Agriculture of each member country.

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